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STRUCTURE OF THE BEREA OIL SAND IN THE FLUSHING QUADRANGLE

HARRISON, BELMONT, AND GUERNSEY COUNTIES, OHIO

BY

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STRUCTURE OF THE BEREA OIL SAND IN THE FLUSHING QUADRANGLE, HARRISON, BELMONT, AND GUERNSEY COUNTIES, OHIO.

By W. T. Griswold.

INTRODUCTION.

The United States Geological Survey has undertaken detailed mapping of the geologic structure of the oil sands in certain parts of the Appalachian oil field in eastern Ohio and western Pennsylvania. The first report describing work of this kind is contained in Bulletin No. 198, which deals with the Cadiz quadrangle in Harrison County, Ohio. The second bulletin is No. 318, which describes the conditions existing in the Steubenville quadrangle in Ohio and West Virginia and in the Burgettstown and Claysville quadrangles in Pennsylvania. The present report, which is the third of the series, treats of the Flushing quadrangle in Harrison, Belmont, and Guernsey counties, Ohio.

The object of this work is to determine accurately the geologic structure of the surface rocks and of the Berea sand (which is the principal oil-bearing stratum of this part of the field), and from this structure to determine, if possible, where the conditions are favorable for the accumulation of oil and gas. The first step in the work is to ascertain the structure or lay of the surface rocks. Then it is necessary to determine what degree of parallelism exists between the rocks that outcrop at the surface and those that lie from 1,000 to 2,000 feet below the surface, and by means of this parallelism to construct a map of the oil sand as if all the geologic formations above it had been removed and the upper surface of the sandstone were open to view.

Previous work of this kind has been carried on in areas in which a considerable amount of oil and gas territory had been developed prior to the survey. In such regions it was possible by means of wells already drilled to check the degree of exactness to which the oil sands could be plotted, and by a study of the conditions under which the oil and gas had accumulated to formulate general laws governing such accumulations.

In the Flushing quadrangle very little oil or gas has been found. It was for this reason that the area was selected for a practical test

of the principles which had been determined in the previous surveys. The Berea sand, which is the principal oil sand of this part of Ohio, was known to be present in this quadrangle. The surface conditions were also known to be favorable for accurate geologic work. By selecting such an area and carefully plotting the structure it was hoped that the areas which are most favorable for the accumulation of oil and gas could be determined, and that thus the economic development of the field would be assisted. The result of the work shows a regularity in the structure which is not favorable for large oil accumulations. There are, however, minor structural features which doubtless have exercised an influence on the location of deposits of oil and gas, and which may be regarded as indicating favorable territory.

The field work in the Flushing quadrangle was performed during the field season of 1906 by B. J. Green and F. M. Hutchinson under the supervision of the writer.

LOCATION, DRAINAGE, AND CULTURE.

The Flushing quadrangle is situated in eastern Ohio and includes parts of Harrison, Belmont, and Guernsey counties. It is limited by meridians 81° and 81° 15′ and by parallels 40° and 40° 15′. The area of the quadrangle is about 227 square miles. It contains no large towns, but there are a number of small places, such as Flushing, Piedmont, Morristown, Belmont, and Bethesda, within it. The city of Barnesville is a little over 1 mile south of the quadrangle, near the southwest corner.

The entire surface of the quadrangle is deeply dissected. The divide separating the waters of Muskingum River from those flowing directly into Ohio River enters the quadrangle in the northeast corner, and extends southward through the eastern third of the quadrangle, passing through the towns of Flushing, Morristown, and Bethesda. East of this divide the topographic features differ materially from those on the west. The streams flowing to the east have a gradual slope at a nearly uniform rate to the eastern edge of the quadrangle; the streams flowing to the west have cut deep canyons nearly to their heads, thus descending to the general valley levels within a very short distance from their sources. Once at those levels they flow westward with very little fall. Between the streams are oval-shaped hills with steep sides. Throughout most of the area the rocks underlying the region are exposed through a vertical section from 300 to 400 feet thick. The surface is in a high state of cultivation and is traversed by roads in all directions.

The Cleveland, Lorain and Wheeling Railway (of the Baltimore and Ohio system) crosses the area from the center of the eastern margin to the northwest corner, and the main Baltimore and Ohio Railroad line passes through the southeast corner.

GEOLOGY.

ROCKS SHOWING AT THE SURFACE.

The rocks which outcrop at the surface of the Flushing quadrangle are included in the Washington, Monongahela, and Conemaugh formations of the Carboniferous system. From the highest to the lowest strata exposed the vertical distance is 740 feet. The base of the Pittsburg coal is accepted as a datum plane from which to commence descriptions and measure intervals. This well-known coal bed is constant over an area covering many square miles and therefore makes a desirable plane from which to reckon. The other members of the formations will be considered from this base, first the overlying and then the underlying beds, the peculiarities of each member being described and the areal distribution of its outcrop given.

MONONGAHELA FORMATION.

The Monongahela formation includes the rocks from the base of the Pittsburg coal to the top of the Waynesburg coal. The principal strata are the Pittsburg, Meigs Creek, Uniontown, and Waynesburg coal beds.

Pittsburg coal.—In this region the Pittsburg coal ranges in thickness from 40 to 62 inches, with an average of about 50 inches in the Flushing quadrangle. The bed is usually divided into three or four benches by small partings of half an inch or less in thickness. One parting is from 14 to 21 inches above the bottom and another about 4 inches higher. The coal is of good quality and generally mined both at local banks and commercial mines. This coal bed is present in most of the quadrangle. In Nottingham Township, Harrison County, it extends westward along the ridge to Prospect Hill. In Moorefield Township the last outcrop to the west is close to the village of Moorefield. In Flushing Township the most westerly outcrops are found on the ridge between Boggs Fork and Stillwater Creek half a mile west of Compher, and to the west of Stillwater Creek in the hills south and east of Oakgrove. Northwest of these last-named outcrops the coal dips to the southeast. It outcrops along the hillsides above Stillwater Creek to a point within a mile of Badgertown. On Boggs Fork and Trail Run the coal remains above water level to a point within a mile of the town of Flushing. East of the main dividing ridge this coal does not come to the surface except for about 2 miles on Crabapple Creek in Wheeling Township, Belmont County. At Laferty, on Wheeling Creek, the coal is about 80 feet below the surface.

Rocks between Pittsburg coal and Meigs Creek coal.—The lower portion of the interval between the Pittsburg coal and the Meigs Creek coal differs greatly in different localities. Normally, the Pittsburg coal is overlain by a few feet of shale extending to a hard blue limestone usually about 1 foot in thickness. Above the limestone is

shale to the Pittsburg Rider coal, which is a small bed from 8 inches to 1 foot in thickness and from 24 to 30 feet above the base of the Pittsburg bed; it is, however, absent over the greater portion of the Flushing quadrangle. Above the Rider coal a second limestone stratum about 1 foot thick is found in many places. Above this is shale for 25 feet or more to a bed of smooth, light cream-colored limestone, from 1 to 2 feet thick, which is especially prominent in the southwest corner of Union, the northwest corner of Goshen, and the eastern side of Warren townships in Belmont County. From this limestone up to the Meigs Creek coal is sandy shale, in places merging into flaggy sandstone.

In a large part of the Flushing quadrangle the lower part of this interval, from the Pittsburg coal to the top of the limestone overlying the Rider coal, is represented by a massive buff sandstone of medium coarseness known as the Pittsburg sandstone. This bed generally commences on top of the coal and in some localities has replaced part of the coal bed. The sandstone is present in the western part of Cadiz Township, through Nottingham Township, and in the eastern part of Moorefield Township, in Harrison County; in the western part of Flushing Township, in Kirkwood Township to the west of Hendrysburg, and through the western part of Warren Township, in Belmont County.

Meigs Creek coal.—The Meigs Creek coal is equivalent to the Sewickley coal bed of Pennsylvania. Throughout a large part of the Flushing quadrangle this coal is of commercial importance, maintaining a thickness of about 4 feet. As a rule the coal is overlain by clay which is flinty in places and ranges in thickness from 8 inches to 2 feet. The clay is locally overlain by a small coal from 6 to 8 inches thick. The Meigs Creek coal maintains a commercial thickness through Athens Township, Harrison County; and in the eastern part of Flushing, the whole of Union, Goshen, Warren, and the southern part of Kirkwood townships, Belmont County.

The interval between the base of the Pittsburg coal and the top of the Meigs Creek coal was measured in 55 different places in the quadrangle, with the results shown in the following table:

Distance between base of Pittsburg coal and top of Meigs Creek coal.

Township.	Number of measurements.	Minimum interval.	Maximum interval.	Average interval.
		Feet.	*Feet.*	*Feet.*
Harrison County:				
Cadiz	4	86	100	94
Athens	7	86	106	96
Belmont County:				
East part of Flushing and Wheeling	7	85	96	91
Union	8	85	101	94
Goshen	1	95	95	95
West part of Flushing	4	99	101	100
North half of Kirkwood	8	95	102	101
South half of Kirkwood	8	94	113	103
Warren	8	101	109	105

Rocks between Meigs Creek coal and Uniontown coal.—The interval between the Meigs Creek and Uniontown coals is occupied by calcareous shale. In places the lower portion contains thin beds of a slabby white limestone which is the equivalent of that portion of the Benwood limestone known as the Dinsmore. Near the center of the interval is often found a bed of hard limestone about 1 foot thick. This bed is not constant enough, however, to make a good reference stratum. The rocks in the upper portion of the interval consist of shale, with here and there a bed of limestone a short distance below the Uniontown coal. In the vicinity and to the east of the town of Flushing the separate limestone beds are better developed than in other parts of the quadrangle.

Uniontown coal.—This coal, which is known as No. 11 of the Ohio series, has a thickness of 8 to 30 inches. It is best developed on Bend Fork south of Bethesda, where it has been mined in a small way. It is here 30 inches thick, with a 2-inch parting of shale 10 inches from the bottom and 1 inch of clay 24 inches from the bottom. The Uniontown coal appears in the high hills in the north part of Athens Township and thence south along the main dividing ridge. On the ridge south of Trail Run it extends westward to Rock Hill. It is generally present in Union, Goshen, Warren, and southern Kirkwood townships in Belmont County.

The distance from the Meigs Creek coal to the Uniontown coal was measured in 19 different places in the quadrangle, with results as shown in the following table:

Distance from top of Uniontown coal to top of Meigs Creek coal and to base of Pittsburg coal.

Township.	Number of measurements.	Meigs Creek coal.			Pittsburg coal—average interval.
		Minimum interval.	Maximum interval.	Average interval.	
		Feet.	*Feet.*	*Feet.*	*Feet.*
Harrison County:					
Cadiz	1	82	82	82	176
Athens	3	80	100	92	188
Belmont County:					
Flushing	4	89	99	95	[a] 186 [b] 195
Union	4	98	108	103	197
Goshen	1	96	96	96	196
Kirkwood	3	90	105	97	199
Warren	3	91	105	98	203

[a] East part. [b] West part.

Rocks between Uniontown coal and Waynesburg coal.—The section between the Uniontown coal and the Waynesburg coal is composed mostly of shale, which is sandy in the upper portion. Below the Waynesburg coal in many places is a limestone, above which is fire clay extending to the bottom of the coal.

Waynesburg coal.—The Waynesburg coal ranges from 20 to 40 inches in thickness and is best developed in the southeast corner of

Union Township and in Goshen Township. This coal is mined in a small way northwest and south of Belmont, where it has a thickness of about 40 inches, with a half-inch parting of shale 19 inches from the bottom.

The distance from the Uniontown coal to the Waynesburg coal was measured in 27 different places in the quadrangle, as shown in the following table:

Distance from top of Waynesburg coal to top of Uniontown coal and to base of Pittsburg coal.

Township.	Number of measurements.	Uniontown coal.			Pittsburg coal—average interval.
		Minimum interval.	Maximum interval.	Average interval.	
		Feet.	*Feet.*	*Feet.*	*Feet.*
Harrison County:					
Athens	2	35	40	37	225
Flushing	4	38	51	43	[a] 229 [b] 238
Belmont County:					
Union	7	36	61	49	246
Goshen	9	37	56	46	242
Kirkwood	1	38	....	(c)	245
Warren	4	47	63	59	262

[a] East part. [b] West part. [c] Goshen average used.

WASHINGTON FORMATION.

The Washington formation includes the rocks from the top of the Waynesburg coal to the top of the Upper Washington limestone. The well-marked strata which occupy this interval in Pennsylvania are not sufficiently developed in the Flushing quadrangle to be easily recognized. The only members positively identified are the Washington coal and the Upper Washington limestone.

Rocks between Waynesburg coal and Washington coal.—Overlying the Waynesburg coal is from 1 to 6 feet of shale, above which is the Waynesburg sandstone. This sandstone, which is of a light-brown color, occurs in layers from 6 inches to 2 feet thick, the combined layers having a total thickness of 15 to 20 feet. Above this is a sandy shale which extends to a bed of easily disintegrated limestone, with 6 to 8 inches of dark-colored fire clay above. The average distance of this clay above the Waynesburg coal is about 52 feet. It probably represents the horizon of the Waynesburg B coal of Pennsylvania. From the clay to the Washington coal is shale, with no distinctive features.

Washington coal.—The Washington coal is present in the southeast corner of the quadrangle, with a thickness of 1½ to 2 feet of solid coal underlain by 6 feet of very black shale. The northernmost outcrop in the quadrangle is in the hill at the crossroads 1½ miles northeast of Morristown. From this place it is found in the higher hills to the southeast and along the main dividing ridge as far west as Speidel.

The distance between the Waynesburg and Washington coals was measured in seven different places in the quadrangle, with the results shown in the following table:

Distance from Washington coal to top of Waynesburg coal and to base of Pittsburg coal.

Township.	Number of measurements.	Waynesburg coal.			Pittsburg coal—average interval.
		Minimum interval.	Maximum interval.	Average interval.	
Belmont County:		*Feet.*	*Feet.*	*Feet.*	*Feet.*
Union	2	99	101	100	345
Goshen	5	89	98	92	334

Rocks between Washington coal and Upper Washington limestone.—The rocks lying between the Washington coal and the Upper Washington limestone are present in the Flushing quadrangle only in the high ridges to the south of the Baltimore and Ohio Railroad. They consist mostly of shale, with one or two limestone beds which could not be identified owing to their poor development and their small area of outcrop.

Upper Washington limestone.—The Upper Washington limestone occurs in the tops of the high ridge in the southeast corner of the quadrangle. It is a double bed, each section of which is about 1 foot thick. Two measurements of the distance of this bed above the Washington coal were obtained, both of which show the interval to be 160 feet. This makes the Upper Washington limestone 494 feet above the base of the Pittsburg coal. This limestone is the highest reference stratum in the quadrangle.

CONEMAUGH FORMATION.

The Conemaugh formation lies below the Pittsburg coal, extending from the base of that bed to the top of the Upper Freeport coal. It contains the Pittsburg, Ames, and Cambridge limestones, all of which are easily identified and can be used as reference strata. Besides these are some local coal and limestone beds, which are available as guides to the geology over small areas. In describing the members of the Conemaugh formation the order of considering the members is reversed, the highest or those nearest the Pittsburg coal being considered first. The distances are computed from the same datum plane (the base of the Pittsburg coal), being, however, down instead of up.

Pittsburg limestone.—The Pittsburg limestone ranges from 1 to 4 feet in thickness. Where the greater thickness is present it is divided into two beds. Its position ranges from a few inches to 25 feet below the base of the Pittsburg coal. Normally there is a foot of fire clay under the coal, with the limestone next below. In many places, however, the limestone is next to the coal and the fire clay below the limestone.

Where the interval between the coal and limestone is 20 feet or more it is occupied by fire clay and shale.

The distance from the base of the Pittsburg coal to the top of the Pittsburg limestone was measured in 12 different places in the quadrangle, with the results shown in the following table:

Distance from top of Pittsburg limestone to base of Pittsburg coal.

Township.	Number of measurements.	Minimum interval.	Maximum interval.	Average interval.
Harrison County:		*Feet.*	*Feet.*	*Feet.*
Cadiz	3	14	20	[illegible]
Belmont County:				
Flushing	1	16	16	[illegible]
Kirkwood	6	0	29	[illegible]
Moorefield	2	0	1	[illegible]

Rocks between Pittsburg limestone and Ames limestone.—The rocks between the Pittsburg limestone and the Ames limestone consist mostly of sandy shale and sandstone. In the vicinity of Cassville, in the western part of Cadiz Township, Harrison County, is a bed of hard limestone with a rough surface, showing on fracture a conglomerate of small particles of limestone, ranging in color from light buff through brown to red. This rock carries a small percentage of iron, which gives a red color to the mud formed when the rock is disintegrated. By two measurements in Cadiz Township this rock was found to be 79 and 96 feet below the Pittsburg coal; two in Nottingham Township gave 72 and 74 feet below the coal; and two in the western part of Flushing Township gave 44 and 58 feet below the coal. The average of all measurements is 70 feet, but the result is not satisfactory, owing to the great variation of the measurements in the different sections.

In Cadiz and Athens townships a coal or black shale 1 foot thick occurs in the interval of 145 feet below the Pittsburg coal. In Moorefield and western Flushing townships this interval is only 115 feet, as determined by the average of five measurements.

In the lower part of the interval between the Pittsburg limestone and the Ames limestone is a massive sandstone from 15 to 30 feet thick. Its base is usually from 10 to 12 feet above the Ames limestone, but in many places the sandstone lies directly above the limestone or has entirely replaced it.

Ames limestone.—The Ames limestone is a bed of hard, green limestone from 1 to 3 feet thick. It contains many fossil crinoid stems and brachiopods, these fossils being most plentiful in the upper portion of the bed. The distance from the base of the Pittsburg coal to the Ames limestone was measured in 13 different places in Flushing, Moorefield, and Kirkwood townships. Eleven of these measurements show an interval ranging from 161 to 176

feet, with an average of 171 feet. Two other measurements show distances of 185 and 147 feet. The average of all measurements is 168 feet.

Rocks between Ames limestone and Cambridge limestone.—The rocks between the Ames limestone and the Cambridge limestone are fully exposed only in the northwest corner of the quadrangle. In order to measure the distance between these two beds of limestone, levels were run a mile or so west of the quadrangle, where outcrops of both beds were crossed. The result of these measurements shows a distance of 74 feet between the two limestones, with a coal 18 feet above the Cambridge. This coal is from a few inches to 2 feet in thickness, and it has been mined in a small way in the northwest quarter of the quadrangle.

Cambridge limestone.—The Cambridge is a dark-gray limestone, weathering to a light yellow. It contains many fossil brachiopods and a few crinoid stems. The distances from the Cambridge coal and the Cambridge limestone to the Pittsburg coal are accepted as 227 and 245 feet, respectively.

Mahoning sandstone.—The top of the Mahoning sandstone, a coarse, buff, massive rock, appears in the northwest corner of the quadrangle. It attains a thickness of about 40 feet just west of the quadrangle boundary. Directly under the Mahoning sandstone is the Upper Freeport coal, which is not exposed in this quadrangle, but is worked along Stillwater Valley just beyond the west side.

ROCKS WHOLLY BELOW THE SURFACE.

The subsurface rocks to be considered are those extending down to and including the Berea sandstone. Knowledge of these rocks is obtained only from the logs of wells. Only a few detailed records were obtained from the wells in the Flushing quadrangle, and these few do not agree with each other closely enough to furnish a description of the rocks. The following are some of the best records obtained:

Log of well[a] (No. 13) on the Margaret Dunlap farm, in Moorefield Township, Harrison County.

	Thickness.	Distance below mouth of well.	Distance below base of Pittsburg coal.
	Feet.	*Feet.*	*Feet.*
Shale, red	61	0	140
Shale, gray	119	61	201
Coal, small bed	2	180	320
Shale	395	205	345
Sand (filled with water)	60	600	740
Shale, soft, dark	140	660	800
Sand, Big Injun	235	800	940
Shale	357	1,035	1,175
Sand, hard, Berea (water)	24	1,392	1,532

[a] Mouth of well, 943 feet above sea. Base of Pittsburg coal at well, 1,083 feet above sea.

Log of well[a] *(No. 42) on the Abner Lodge farm in Union Township, Belmont County.*

	Thickness.	Distance below mouth of well.	Distance below base of Pittsburg coal.
	Feet.	*Feet.*	*Feet.*
Coal, Meigs Creek	4	25	[b] 97
Limestone	87	29	[b] 93
Coal, Pittsburg	5	117	[b] 5
Shale	5	112	0
Limestone	113	127	5
Sand	45	240	118
Shale	375	285	163
Coal, Upper Freeport	6	660	538
Shale	66	666	444
Coal	10	726	604
Shale	104	736	614
Sand	50	840	718
Shale	50	890	768
Sand, Salt sand	60	940	818
Shale	25	1,010	888
Sand and broken shells	20	1,035	913
Shale, black	10	1,055	933
Sand, Big Injun	225	1,065	943
Shale	59	1,290	1,168
Limestone	240	1,349	1,227
Shale	35	1,589	1,467
Shale, brown	11	1,624	1,502
Sand, Berea	35	1,635	1,513

[a] Mouth of well, 1,106 feet above sea. Base of Pittsburg coal at well, 984 feet above sea.
[b] Above base of Pittsburg coal.

Log of well[a] *(No. 53) on the Albert Romans farm in Londonderry Township, Guernsey County.*

	Thickness	Distance below mouth of well.	Distance below base of Pittsburg coal.
	Feet.	*Feet.*	*Feet.*
Limestone, Ames	3	23	171
Coal	6	226	374
Sand, white	6	320	468
Coal	4	332	480
Sand, white	35	336	484
Coal	3	446	594
Sand (with salt water)	12	458	606
Coal	5	485	633
Sand, gray	20	490	638
Sand, Hurry-up	40	545	697
Sand (show of oil; water at 720 feet)	66	654	802
Sand	20	840	988
Shale	37	860	1,008
Sand, gray (show of oil)	20	897	1,045
Shale, black	39	917	1,065
Sand, Big Injun	89	956	1,104
Sand, Berea	37	1,407	1,555

[a] Mouth of well, 1,164 feet above sea. Base of Pittsburg coal at well, 1,312 feet above sea.

Log of well[a] *(No. 67) on the P. E. Calhoun farm in Londonderry Township, Guernsey County.*

	Thickness.	Distance below mouth of well.	Distance below base of Pittsburg coal.
	Feet.	*Feet.*	*Feet.*
Sand	15	10	214
Shale, red	10	25	229
Shale, white	15	35	239
Shale, red	5	50	254
Limestone, blue	41	55	259
Coal	2	96	300
Limestone, white	27	98	302
Shale, red	20	125	329
Limestone	30	145	349
Shale, black	50	175	379
Limestone, white	25	225	429
Coal	3	250	454
Shale, white	25	253	457
Sand	10	278	482
Shale, black	12	288	492
Shale, white	15	300	504
Limestone, white	30	315	519
Sand, white	25	345	549
Shale, black	15	370	574
Limestone, black	15	385	589
Sand, white	20	400	604
Shale, black	10	420	624
Limestone	50	430	634
Shale, black	15	480	684
Sand, white	45	495	699
Shale, black	47	540	744
Limestone	53	587	791
Sand, white, Keener	90	640	844
Shale	30	730	934
Sand, Big Injun	200	760	964
Shale	40	960	1,164
Limestone	65	1,000	1,204
Shale	110	1,065	1,269
Sand and shale	37	1,240	1,444
Shale, black	33	1,277	1,481
Sand, Berea	19	1,310	1,514

[a] Mouth of well, 1,025 feet above sea. Base of Pittsburg coal at well, 1,229 feet above sea.

Log of well[a] *(No. 98) on the F. M. Taggert farm in Union Township, Belmont County.*

	Thickness.	Distance below mouth of well.	Distance below base of Pittsburg coal.
	Feet.	*Feet.*	*Feet.*
Shale	89	21	[b] 188
Coal, Meigs Creek	5	110	[b] 99
Limestone and shale	90	115	[b] 94
Coal, Pittsburg	4	205	[b] 4
Limestone and red shale	430	209	0
Shale, white and black	60	639	430
Shale, brown	40	699	490
Sand, gray, First Cow Run	55	739	530
Shale	112	794	585
Sand, Second Cow Run	107	906	697
Shale, black	12	1,013	804
Sand	40	1,025	816
Limestone and shale	61	1,065	856
Sand, Keener (show of oil and gas)	40	1,126	917
Shale, white	5	1,166	957
Sand, Big Injun	237	1,171	962
Shale	60	1,408	1,199
Limestone and shale	272	1,468	1,259
Sand, Berea (salt water)	28	1,740	1,531

[a] Mouth of well, 1,193 feet above sea. Base of Pittsburg coal at well, 984 feet above sea.
[b] Above base of Pittsburg coal.

RESULTS OF THE WORK.

OBJECT.

The object of the work in the Flushing quadrangle was to produce a map of the Berea oil sand with as great a degree of accuracy as was possible from the geologic conditions, and with sufficient detail to make it of value to the practical oil man in the location and development of oil and gas territory.

In work of this character there are two conditions which govern the accuracy of the final result. These are (1) the degree of parallelism that exists between the outcropping strata and the oil sand, and (2) the regularity of the variation in the distance between these beds.

SUBSURFACE MAPPING.

GENERAL STATEMENT.

The mapping of a subsurface stratum consists of three distinct steps:

First, it is necessary to find the elevations of the outcrops of different known strata; then, having determined the average distance and the variations in this distance between these strata, by combining these data to prepare a contour map showing the geologic structure of some prominent stratum called a key rock.

Second, by means of the measured depth to the oil sand from the mouths of test wells already drilled, to determine by leveling to these wells the distances in different parts of the area between the key rock and the oil sand it is proposed to map.

Third, by means of a mechanical drawing called a convergence sheet to correct for the variations in distances between the key stratum and the oil sand in different parts of the area, and then to project the elevations obtained upon the key horizon, thereby determining the correct elevation of the oil sand.

BASE MAP.

The first requisite in this work is a good topographic base map upon which to indicate the horizontal locations of the outcrops of different strata. The base map of the Flushing quadrangle is the topographic atlas sheet surveyed in 1903 by the United States Geological Survey. On this map were located in horizontal position the outcrops of the different strata. The elevation of the outcrops at each of these points was obtained by a spirit level which was run from permanent bench marks established by the topographic engineers. For this work the level lines were carried over all roads, up a great many streams, and along a number of ridges. In this way the elevations of the outcrops all over the quadrangle were obtained.

MEASUREMENT OF INTERVALS.

The intervals between the different surface strata were obtained by comparing the elevation of outcrops of different strata where they are near together and where the elevation of the outcrop of one stratum could be compared with the elevation of two outcrops of another stratum on different sides of the first. In this way a great many comparisons were made, and the average distance between the beds in the different townships was obtained. The results of this work have been given under the heading "Geology." In considering these results with a view to determining what degree of accuracy can reasonably be expected in the structure map of the key horizon, it is found that out of 51 measurements of the distance between the Meigs Creek coal and the Pittsburg coal, when averaged by townships, the minimum and maximum in each township are within 10 feet of the average, and that the range is usually nearly 20 feet when a number of measurements are taken. The same condition holds for the distances between the prominent beds above the Meigs Creek coal. The Pittsburg limestone, whose distance below the Pittsburg coal is from a few inches to 29 feet, has the same range of variation as the strata at distances of 200 or 300 feet from the Pittsburg coal. This indicates that there is a local divergence from parallelism between the different strata of about 20 feet, that the average distance between strata over small areas will give results that are probably correct within 10 feet, and closer accuracy than this is not to be looked for.

The distance of 171 feet between the Pittsburg coal and the Ames limestone in the northwest quarter of the Flushing quadrangle is believed to be very nearly correct. This probably diminishes from the south and east toward the northwest. The measurements of this interval made in the central and western parts of the Cadiz quadrangle ranged from 205 to 230 feet. The determination of the distance from the limestone bed lying between the Pittsburg limestone and the Ames limestone to the Pittsburg coal is poor. All measurements show this interval to vary abruptly from east to west. The position of the Cambridge limestone and the coal above it with reference to the Ames limestone was determined at only a few places, but the measurements so obtained are believed to be good.

SURFACE STRUCTURE MAP.

As the Pittsburg coal is the most prominent outcropping stratum in the quadrangle, its base is accepted as the key horizon by which the structure of the surface rocks is represented. The elevation of the outcrops of this horizon were determined wherever possible directly with a spirit level. To the determined elevation of every

other outcropping horizon was added or subtracted the average distance of that particular horizon below or above the base of the Pittsburg coal in that township. This resulted in establishing the elevation of the Pittsburg coal at nearly 900 locations. The points of equal elevation were connected by lines, thus forming a contour map of the bottom surface of the Pittsburg coal (Pl. I). Data for making the surface structural map are plentiful in all parts of the Flushing quadrangle, except in a portion of Moorefield and Freeport townships, Harrison County. In the area to the north and west of the village of Piedmont the Ames limstone seems to be absent. It is probable that the sandstone whose base is normally from 10 to 12 feet above the Ames limestone has descended and cut out the limestone. The absence of this important stratum leaves the limestone between the Pittsburg limestone and the Ames limestone and a few outcrops of what is believed to be the Cambridge coal as the only beds from which to determine the structure. The scarcity of information has made it impossible to draw contours with any degree of accuracy in this area.

STRUCTURAL FEATURES.

The structural features represented on Pl. I are not pronounced but rather monotonous. The dip of the rocks is to the southeast with but little irregularity. The most prominent feature is the structural dome at Smyrna. Here the Pittsburg coal if it had not been eroded would lie at an elevation of about 1,300 feet, or 60 feet above the surface. Due east from this dome is a steep dip of about 160 feet. This is the steepest dip found for any considerable distance in the quadrangle. From the Smyrna dome an anticlinal ridge extends to the southeast, falling away at a steep angle into a synclinal trough on the south. A second dome of lesser magnitude exists just north of the town of Fairview.

A structural feature that is important, though not prominent, is the anticlinal ridge which commences in the northwest corner of the quadrangle, swings a little to the south and thence trends northeast, leaving the quadrangle a little east of the center of the northern boundary. The western portion of this ridge shows a drop of about 60 feet to the northeast into a basin on the north edge of the quadrangle. The geologic evidence regarding the depth of this basin is not of the best, as nothing but outcrops of what is believed to be the Cambridge coal were found within the area. This coal is known to dip as represented by the contours. This dip, however, may not coincide with the dip of the adjacent rocks. The northern dip from the anticlinal ridge farther to the east is more positively established by elevations on the Ames limestone and the Pittsburg coal, some of which are north af the quadrangle. The dip is slight, however,

being in all not over 20 feet. In Athens Township, Harrison County, a secondary fold exists to the south of the main anticlinal ridge. The northward dip from this fold is very slight, being in places less than one contour interval.

The remaining noticeable feature of the quadrangle is a slight dome 2 miles northeast of Flushing, whose northwesterly dip is over 20 feet. The existence of this feature is established by elevation on both the Meigs Creek and the Uniontown coal.

CONVERGENCE SHEET.

With the surface structure defined by the elevations of the Pittsburg coal as shown on Pl. I, the next step was to determine the amount to be subtracted from each elevation to make it equivalent to an elevation on the top of the Berea sand. This information was gained from wells already drilled within the area. The quadrangle was carefully searched for any existing wells or previously drilled dry holes and it is believed that all the test wells drilled prior to the date of the survey are represented on the map of the Berea sand. The elevation of the mouth of each well was obtained by spirit level. With this information the position of the key horizon with reference to the mouth of the well is obtained from Pl. I, and by a slight calculation the distance from the key horizon to the oil sand is obtained from the record of the well. The records of 28 wells on or adjacent to the quadrangle were obtained. From these records was built up the convergence sheet, which is constructed by connecting the positions of the different test wells by straight lines and then dividing these lines so that each subdivision represents the horizontal distance in which the vertical interval between the Pittsburg coal and the Berea sand decreases or increases 10 feet. The distance from the base of the Pittsburg coal to the top of the Berea sand was found to range from 1,464 feet to 1,613 feet, the lesser interval being along the north edge and the greater near the southwest corner of the quadrangle The interval does not increase regularly, however, but ranges from 1,464 to about 1,540 feet in the north third of the quadrangle, decreases to a little over 1,500 feet in the central part, and then increases at a uniform rate to the maximum distance at the south edge. A large area in the center of the quadrangle is devoid of any drilled well from which a record could be obtained. The assumption of an even increase or decrease over distances as great as those between some of the wells from which the convergence sheet of the Flushing quadrangle is made up is undesirable, but could not be avoided.

MAP OF THE BEREA OIL SAND.

With the previously described work performed, the construction of the map of the oil sand is very simple. The convergence sheet shows the amount to be subtracted from each elevation of the key horizon.

This amount in the Flushing quadrangle was in all cases greater than the elevation of the key horizon, showing the oil sand to be everywhere below sea level. To avoid the use of the minus sign in numbering the contours of the oil sand, 2,000 feet were added to each elevation of the key horizon. This is equivalent to assuming a datum plane 2,000 feet below sea level for the map of the oil sand. After subtracting the amount shown in the convergence sheet from each elevation of the key horizon, the points of equal elevation were connected by lines. The result is a contour map of the Berea oil sand as shown in Pl. II, on which the upper surface of the limestone cap of the Berea sandstone is represented by contours printed in red. The elevations of these contours are shown by numbers figured from a datum plane 2,000 feet below sea level. All wells known to have been drilled prior to the date of survey are also shown in red with accepted symbols for dry holes, gas wells, and oil wells. Wells known to have been drilled only to some of the upper sands are marked with a cross to the left of the well symbol.

FACTORS GOVERNING THE ACCUMULATION OF OIL AND GAS.

Previous work of this kind has demonstrated that there are three primary factors which govern the accumulation of oil in the rocks. These are (1) the condition of the rocks as to porosity, (2) the area of complete saturation by water of the oil-bearing stratum, and (3) the geologic structure of the rocks.

POROSITY.

The condition of many of the sands changes within short distances from loose and porous sands to closely cemented hard rocks entirely impervious to oil and water in large quantities. Some sandstone beds are of the same texture over large areas, both as to the size of the solid particles forming them and as to the matrix which combines the separate grains. In others, although the size of the separate grains remains relatively the same, the cementing material changes from place to place and in this way the relative porosity of the rock is changed. Some sandstone beds contain lenses of conglomerate in which the separate particles are of considerable size, loosely held together, thus forming a condition of great porosity. A knowledge of the general characteristics of a particular sandstone bed is gained only by test wells. In the Appalachian oil field the peculiarities of the principal oil-bearing sands are pretty well known.

SATURATION.

The condition of saturation with water is not the same in different sands. Experience has shown that the older or lower beds in the Appalachian field contain a smaller area of completely saturated rock

than the upper or younger sands. The lowest sands seem to be almost entirely dry, only the very lowest points in the center of a structural basin showing any considerable quantity of salt water. Above these lower rocks each succeeding stratum of sandstone has a larger area in which it is saturated with water. In regions where the sand rock is not entirely saturated there may be separate areas of saturated rock in each structural basin, the upper limits of which are at the same elevation in any one basin but at different elevations in different structural basins.

STRUCTURE.

The effect of geologic structure on the accumulation of oil depends on the condition of saturation of the oil-bearing stratum.

If small quantities of oil and gas are in a dry, porous rock at different points the oil will move down as long as the slope is sufficient to overcome friction and capillary attraction. The gas will diffuse with the air or water vapor contained in the pores of the rock.

Oil and gas in a porous rock that is completely saturated with water will first be forced up to the top of the porous stratum by the difference in the specific gravity of the oil and the water. The oil and gas will accumulate in the upper part of the rock if the porous stratum is level, but if it dips sufficiently to overcome friction the particles of oil and gas will gradually be forced up the slope, the gas with its much lower specific gravity occupying the higher places.

In places where the porous rocks are only in part completely saturated a combination of these two actions will take place. The oil above the line of complete saturation will run down to that line and the oil below will be forced up to the top of the completely saturated portion.

The sand spoken of as porous may not be so at all points. If in some areas it is impervious, those areas will tend to limit the movement of the oil and gas through the rock. Although a short distance away the same stratum may be porous, it must from an oil standpoint be considered a separate and distinct porous body, unless the area of impervious rocks is so situated that the oil can readily move laterally around it.

PLACES OF ACCUMULATION.

In dry, porous rocks the principal points of accumulation of oil are at the bottom or near the bottom of the synclines, at the lowest points of the porous medium, or at any points where the slope of the rock is not sufficient to overcome capillary attraction and friction, such as structural terraces or benches. In porous rocks that are completely saturated the accumulation of both oil and gas will be in the anticlines or along level portions of the structure. In completely saturated rocks of small area the accumulation should occur

at the highest point of the porous medium, and where stops or dams of impervious rocks exist in a generally porous stratum the accumulation should occur below such impervious stop, which is really the top limit of the porous rock. In porous rocks that are only partly filled with water the oil accumulates at the top limit of the saturated area. This point may be anywhere with reference to the anticlines and synclines.

The condition most generally found is that the rocks are saturated only in a portion of their volume, in which case accumulations of oil may occur anywhere with reference to the geologic structure, though they are more likely to be on terraces or levels, as these points are favorable to accumulation in both dry and saturated rocks.

Under all conditions the most probable location for the accumulation of gas is in an anticline, though small folds along the side of a syncline may capture and hold a supply of gas, or the rocks may be so close-grained that gas can not travel to the anticline, but must remain in greatest volume close to the oil accumulation.

CONDITIONS IN THE FLUSHING QUADRANGLE.

SATURATION OF BEREA SAND.

In the Flushing quadrangle the Berea sand lies in the same structural basin as in the southeastern half of the Cadiz quadrangle. In that portion of the Cadiz quadrangle it was found to be completely saturated to an elevation of about 270 to 280 feet below sea level. This is equivalent to an elevation of 1,720 to 1,730 feet, as the contours on the Flushing quadrangle are numbered. This is higher than any portion of the sand in the Flushing quadrangle, except a very small area on top of the Smyrna anticline. The conditions, therefore, to be considered in this area are those of complete saturation. Under these conditions the oil should accumulate just below the gas on the crest of the anticlinal ridges and upon terraces at the top of steep breaks.

EXISTING OIL POOLS.

Only three oil pools have been discovered in the Flushing quadrangle. The Uniontown pool, in Wheeling Township, on the east edge of the quadrangle, extends eastward into the St. Clairsville quadrangle for a short distance. This pool is located on a large structural flat or terrace, only a small portion of which is covered by it. The pool appears to be well defined within the quadrangle by dry holes. To the southeast the structure shows a descent of about 40 feet. This is not favorable for the accumulation of oil unless a steep slope of some magnitude exists in the St. Clairsville quadrangle.

In the southwestern portion of the quadrangle is the north end of the Barnesville pool. This accumulation is on a slope as shown by

the contours. From the separate well records, however, a very narrow terrace can be recognized. The direction of the pool is along the strike of the rocks for 1 to 2 miles to the south and then to the west, the elevations of the sand differing by only a few feet in all wells where oil was found.

The third pool in the quadrangle is at Oakgrove. This is the only accumulation so far discovered in the quadrangle that could have been foretold by a knowledge of the structure prior to the drilling of the wells. The location of the pool is upon a flat near the top of the Smyrna anticline. All wells so far developed are small, and a number of dry holes are close to the producing wells. The wells are not in the best theoretical location for large production. The eastern side of the anticline along the Guernsey-Belmont county line in secs. 32 and 33 appears to be the most favorable territory from a structural standpoint. From this point to the east is a strong dip of 160 feet. Near the top of this slope is the theoretical location for oil accumulation. The flat on the structural nose in the southern part of sec. 31, Flushing Township, Belmont County, looks favorable and is certainly worthy of a test well.

TERRITORY FAVORABLE FOR NEW DEVELOPMENT.

North of the village of Fairview, in the northern part of sec. 2, Oxford Township, Guernsey County, is a structural dome in which there is probably an accumulation of both oil and gas.

North of Morristown is a very low dome, including all of sec. 21, Union Township, Belmont County. The position of this dome is established by elevations on a number of the upper coal beds. It is probable that this feature extends down to the Berea sand. If the map is a true representation of the oil sand, this dome is a favorable point for both oil and gas. On its western side a number of wells have been drilled which produced gas from the upper sands. Wells Nos. 81 and 98 were drilled to the Berea sand and reported dry. They should not, however, condemn the entire area.

In the northern part of sec. 10 and southern part of sec. 11, Athens Township, Harrison County, is represented an anticlinal dome whose northern dip is 20 feet or more. This feature is established by levels on the Meigs Creek coal. The conditions as represented should be favorable for both oil and gas.

Along the north edge of the quadrangle, in secs. 1, 3, and 8 of Nottingham Township, Harrison County, is an anticline, and to the south of this ridge near Cassville is a second anticlinal fold. These features, are not prominent, but they are important owing to the slight northward dip of the formation. This northward dip is well established by levels on the Pittsburg and Meigs Creek coals. The

main or northern anticline is a direct extension from the Moholland oil pool, which lies 1 mile to the northeast in the Scio quadrangle. This pool was discovered and partly developed during the summer of 1906. The crest of the anticline through the sections mentioned is favorable territory. The secondary anticline to the south is detrimental to the chances of oil on the main ridge, as its own dome may have trapped the oil.

WELLS IN THE FLUSHING QUADRANGLE.

The following table sets forth such information as was procured about the wells drilled in the Flushing quadrangle. It states in concise form the owner of the land on which the wells were drilled; the number of them; the person by whom they were drilled; the elevations of their mouths above sea level; the distance from their mouths to the top of the Berea sand, and their total depths. The reference numbers of the wells correspond to those given on the map (Pl. II).

List of wells in the Flushing quadrangle.

No. on Pl. II.	Owner of land.	Number of wells.	Well drilled by—	Elevation of mouth.	Depth to Berea sand.	Total depth.	Remarks.
				Feet.	*Feet.*	*Feet.*	
1	H. S. Barricklow	1	Rankin Gas Co.	1,015	1,415	1,480	Gas and small show of oil in Berea sand.
2	....do	2	....do	1,035			Gas in Cow Run sand.
3	....do	1	Rich Oil and Gas Co.	1,074	1,470	1,524	Dry.
4	W. K. Scott	1	Rankin Gas Co.	1,004		704	Gas in Cow Run sand.
5	Mary Rankin	1	....do	979	1,376	1,417	Gas in Berea sand.
6	R. K. Dunlap	2	....do	981	1,372		
7	W. F. Dunlap	1	....do	1,020	1,416	1,477	Little gas.
8	J. F. Dickerson	1	....do	971	1,388		Dry (no water).
9	John D. Barricklow	1	Hedge & Holmes	1,096			Dry.
10	S. M. McDowell	1	W. D. Black & Co.	1,054	1,447	1,499	Dry (no water).
11	M. A. Johnson	1	....do	1,011	1,432	1,478	Dry (no water); show of oil.
12	S. M. McDowell	2	....do	1,062	1,488		Dry.
13	Margaret Dunlap	1	....do	943	1,392	1,437	Little water.
14	Samuel Richey	1	Charles Schoenfield	1,068			Small show of oil and gas.
15	W. F. Dunlap	1	W. D. Black & Co.	1,077	1,517	1,562	Salt water.
16	R. N. Birney	1		1,131			
19	Sarah J. Lyle	2	National Oil Co.	1,200	1,718	1,742	Producer.
20	Josiah Beall	3	....do	1,216	1,728	1,758	Do.
21	....do	2	....do	1,226	1,738	1,765	Do.
22	....do	4	....do	1,170	1,690	1,712	Do.
23	Sarah J. Lyle	1	....do	1,145	1,657	1,680	Do.
24	Josiah Beall	1	....do	1,181	1,691	1,721	Do.
25	Clark Boyd	1	....do	1,120	1,637	1,661	Do.
26	—— Lee	9	....do	1,175	1,678	1,706	Do.
27	M. L. Richey	4	....do	1,129	1,658	1,672	Small producer.
28	....do	2	....do	1,157	1,670	1,691	Producer.
29	....do	1	....do		1,598	1,611	Do.
30	....do	3	....do	1,235	1,749	1,795	Salt water.
31	Sarah Lee	8	....do	1,077			Producer.
32	....do	7	....do	1,041	1,568	1,590	Do.
33	....do	3	....do	1,060	1,589	1,608	Do.
37	....do	6	....do	1,006	1,530	1,549	Do.
41	James Lyle	1	....do	1,125	1,650	1,677	Salt water.
42	Abner Lodge	1	....do	1,106	1,635	1,700	Do.
43	Elizabeth Lyle	1	R. D. Gillespie	1,223	1,742	1,770	Do.
44	....do	1	Russell & Bush	1,125	1,653	1,687	Salt water; show of oil.
45	William Walker	1		1,099			Dry.
46	Robert Campbell	1		1,110		1,680	Salt water.
47	John Hazen	1	Freehold Oil and Gas Co.	1,123	1,660	1,699	
48	John Brokaw, sr.	1		1,128	1,635		Do.
49	Byron Cochran	1		1,044			

List of wells in the Flushing quadrangle—Continued.

No. on Pl. II.	Owner of land.	Number of wells.	Well drilled by—	Elevation of mouth.	Depth to Berea sand.	Total depth.	Remarks.
				Feet.	*Feet.*	*Feet.*	
50	Jane Moore		Gilbert & Co.	992	1,370	1,408	Salt water.
51	Harrison Howell	1	do	952	1,352	1,400	Do.
52	R. W. Scott	1		896			Do.
53	Albert Romans		Piedmont Oil and Gas Co.	1,164	1,407	1,444	Do.
54	William Greenfield	1	Elk Creek Oil and Gas Co.				Show of oil.
55	do	1	Piedmont Oil and Gas Co.				Do.
56	O. B. Hibbs	1	do	1,018	1,274	1,296	Small well.
57	do	1	D. F. Conley	1,139	1,391	1,410	Do.
58	do	2	do				Small well; show of oil.
59	do	1	Oak Grove Oil Co.	1,085	1,336	1,352	Producer.
60	do	2	do	1,135	1,385	1,405	Do.
61	C. J. Hibbs	1	Piedmont Oil and Gas Co.				Salt water.
62	do	1	Davis & Goodman		1,410	1,436	Do.
63	William Kirk	1	Allegheny Oil and Gas Co.				Do.
64	William Greenfield	1	do				
65	William Kirk	1	Oak Grove Oil Co.	1,006	1,260	1,282	Producer.
66	George Clay	1	Piedmont Oil and Gas Co.				Salt water.
67	Jobe Reynolds	1	P. E. Calhoun	1,025	1,310	1,369	Little salt water.
68	Harrison Mills	1	H. G. Twiker	941	1,460	1,504	Salt water (record poor).
69	L. B. Bethel	1		884			Salt water.
70	Jos. Barclay	1		906	1,230	1,264	Do.
71	Ellis Fulton	1	J. S. Wilson	906			Do.
72	Eliza Wilson	1	American Oil and Development Co.	1,164	1,521	1,545	Small amount of salt water.
73	W. W. McKebben	1	New York Oil and Gas Co.	998	1,365	1,414	
75	R. K. Dunlap	1		1,020	1,427	1,482	
76	A. J. Rea	1	W. D. Black & Co.	993	1,338	1,402	Dry.
77	Rebecca White	1	Flushing Co.	1,082			Salt water.
80	William Sheppard	2	Rich Gas Co.				Gas in Big Injun sand (shallow well).
81	do	1	do				Salt water in Berea sand.
82	Albert Schlentz	1	do				Gas in Keener sand.
83	J. H. Majors	3	do				Gas in Big Injun sand (shallow well).
84	do	1	do	1,143			Gas in Keener sand (shallow well).
85	do	2	do				Gas in Salt sand (shallow well).
86	Jos. Sheppard	1	do			1,022	Gas in Keener sand (shallow well).
87	do	2	do				Salt water in Keener sand (shallow well).
88	James Barber	1	do				Gas in Salt sand (shallow well).
89	do	2	do				Salt water in Big Injun sand (shallow well).
90	do	3	do				Gas in Salt sand (shallow well).
91	Jos. Easton	1	Morristown Oil and Gas Co.	1,157			Salt water in Berea sand; gas in Keener sand.
92	do	1	St. Clair Oil and Gas Co	1,159			Gas in Keener sand.
93	Arthur Brown	1	do	1,100			Salt water in Keener sand.

94	....do	1	Ann Oil Co	1,251			Salt water in Berea sand.
95	E. Pratt	1	St. Clair Oil and Gas Co	1,215			Gas in Keener sand.
96	Sarah Jeffrey	1	Ann Oil Co	1,067			Small show of oil and water in Keener sand.
97	Lincoln Lynn	1	St. Clair Oil and Gas Co	1,265			Salt water (shallow well).
98	F. M. Taggert	1	Morristown Oil and Gas Co	1,193	1,740	1,768	Salt water.
99	George Dallas	1	Rich Gas Co				Salt water in Keener sand (shallow well).
100	J. D. Sheppard	1	St. Clair Oil and Gas Co	934			Do.
101	David Majors	1	....do				Salt water in Salt sand (shallow well).
102	I. N. Roby	1	....do	932			Gas in Keener sand; salt water in Berea sand.
103	O. C. Ayers	1	....do	933			Gas in Salt sand (shallow well).
104	James Taggert	1	....do	1,002		744	Gas in Salt sand.
105	Theo. Burgess	1	Haycock & Co	973			
106	Willard Hyde	1	Ann Oil Co	1,010	1,582	1,610	Dry.
107	T. Y. Johnson	1	....do	1,142			
108	L. K. Russell	1		1,011			Show of oil in Berea sand.
109	John Walker	1	Ann Oil Co	1,119	1,702	1,750	Dry.
110	Jos. Patterson	1	....do	1,231	1,720	1,730	
111	Martha Brown	1	....do	1,237		1,234	Keener sand at 1,219 feet; salt water.
112	Ann Tidball	1	Hughes & Guffey	948			
113	Henderson Griffin	2	N. D. Goe	1,089			Salt water.
114	J. D. Saltsgaver	3	P. E. Calhoun	1,092		1,596	Do.
115	Benjamin Giffie	1	Andy Crowl	952			
116	....do	2	N. D. Goe	943			
117	....do	3	Andy Crowl	1,002			
118	A. J. Wheaton	1	P. E. Calhoun	1,201			Salt water in Berea sand.
119	John McCormick	1	Husband & Inskep	1,072			Do.
120	James Wilkin	1	P. E. Calhoun	1,163			Dry in Berea sand.
121	Charles Rice	1		1,089			Shallow well.
122	Louis Palmer	1	St. Clair Oil and Gas Co	1,085			Shallow well (water).
123	Jos. Heed	1	Wm. Beadling	1,043			Salt water in Berea sand.
124	Elmer Irwin	1		1,080			Do.
125	Joshua Hogue	1		1,067			
126	Wood Bentley	1	Wm. Beadling	1,054			Do.
129	William H. White	1	St. Clair Oil and Gas Co				Shallow well.
131	John Moran	1	J. B. Knots	927		1,248	Very little salt water in Berea sand.
132	Clark Wells	1	St. Clair Oil and Gas Co	1,064			
133	Jos. Bernard	1	Quaker Oil Co	1,059	1,750		Salt water.
134	Bradfield Bros	1	Hughes & Guffey	1,192			Do.
135	Marion Ault	1	American Oil and Development Co	1,041			Small well.
136	George Gibson	1	Ohio Fuel and Supply Co	1,037	1,613	1,623	Producer.
137	F. S. Walton	1	American Oil and Development Co	1,175	1,748	1,763	Do.
138	John Hayes	1	....do	1,082	1,652	1,671	Do.
139	Jos. Cannon	1	....do	1,068			Do.
140	Margaret Septer	1	....do	1,100	1,668	1,685	Do.
141	James Gill	1	....do	1,052			Do.
142	Amanda Dyer	1	....do	1,089	1,660	1,668	Do.
143	C. Gill	1	....do	1,052	1,624	1,638	Do.
144	Valentine Ault	2	....do	1,208	1,781	1,798	Do.
145	F. S. Walton	2	....do	1,160	1,740	1,754	
147	Jos. Duglass	1	Warren Oil and Gas Co				Dry.
148	Kate Maldon	1	American Oil and Development Co	1,203	1,776	1,790	Producer.

List of wells in the Flushing quadrangle—Continued.

No. on Pl. II.	Owner of land.	Number of wells.	Well drilled by—	Elevation of mouth.	Depth to Berea sand.	Total depth.	Remarks.
				Feet.	*Feet.*	*Feet.*	
149	Kate Maldon	2	American Oil and Development Co.	1,090	1,664	1,679	Producer.
151	....do	4	....do	1,269			Do.
152	Curtis Smith	2	T. N. Barnsdall	1,220			Do.
172	John Laughlin	3	Ohio Fuel and Supply Co.		1,758	1,768	Gas.
175	Campbell Bros.	1	Warren Oil and Gas Co.	1,668			
176	W. O. Dunbar	1	C. K. O'Hara	951	1,278	1,300	Salt water.
183	W. S. Parker (heirs)	1	Ohio Fuel and Supply Co.	1,075	1,601	1,633	Dry.
184	Jos. Kirk	1	Lick Run Oil and Gas Co.	1,104	1,363	1,378	Producer.
185	James Rowland	1		940	1,289	1,319	Salt water.
186	W. A. Fulton	1	A. J. Wallace	1,159			Drilling.
187	Jos. Kirk	2	Lick Run Oil and Gas Co.	1,145	1,403	1,420	Producer.
188	Miller Greenfield	1	McMath & Kelly				Gas in Salt sand.

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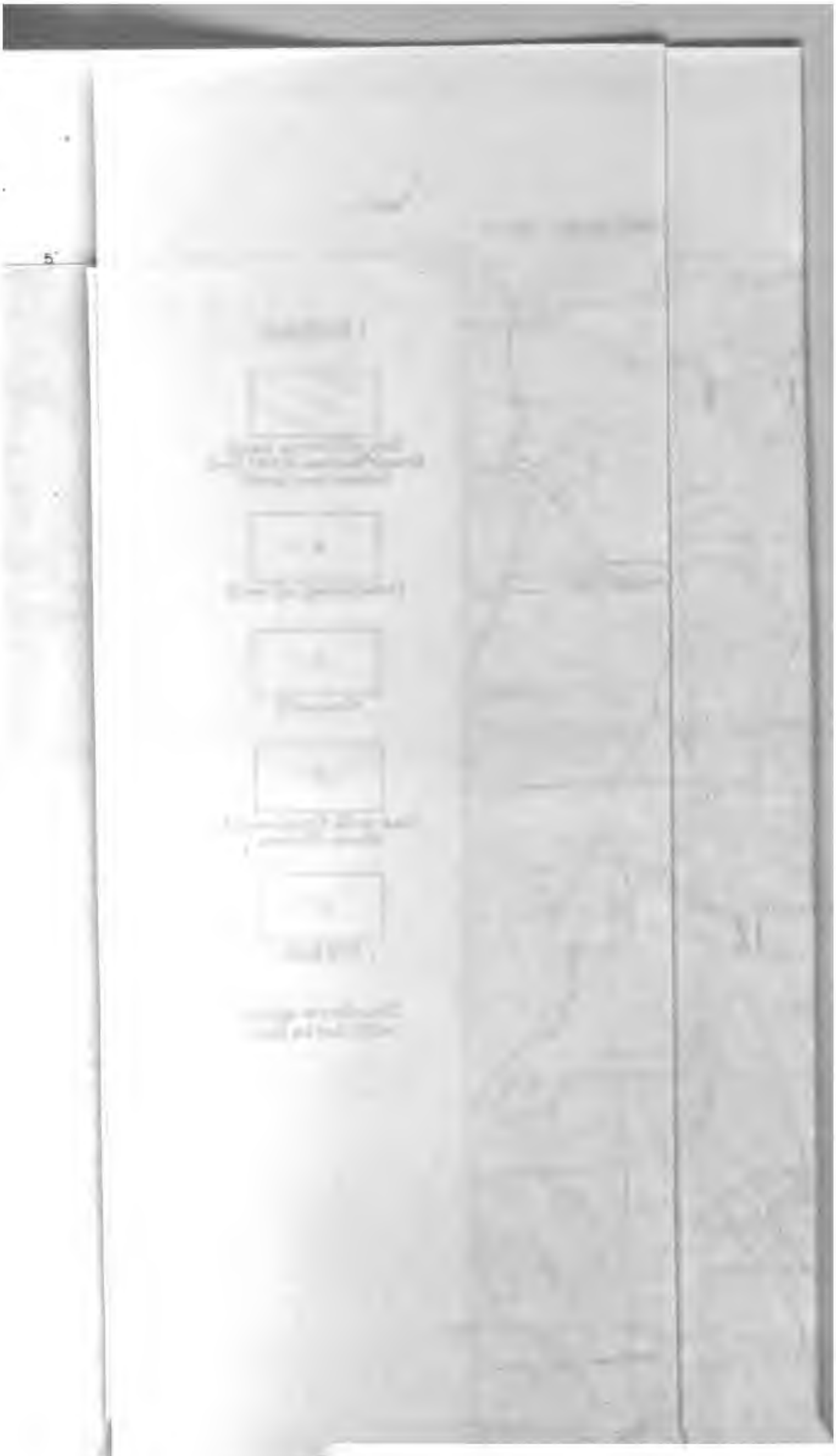

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 347

THE KETCHIKAN AND WRANGELL MINING DISTRICTS, ALASKA

BY

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AND
CHARLES WILL WRIGHT

WASHINGTON
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ILLUSTRATIONS.

PREFACE.

By Alfred H. Brooks.

Though southeastern Alaska, because of its important mining interests, was one of the first fields in the Territory to be investigated by the Geological Survey, yet up to 1902 the work in this region had not advanced beyond the cursory examination of some of the more important districts. In 1902 a topographic survey of a small area near Juneau was completed, and was followed during the next year by the geologic mapping of the same area and the extension of a geologic reconnaissance over a considerable adjacent region. The publication of the results of these surveys[a] marks the first steps in the systematic investigation of this field. The present report embodies the results of the extension of these studies southward to the southern boundary of the Territory. With its publication a preliminary statement of the mineral resources of the three most important mining districts of southeastern Alaska—the Juneau, the Wrangell, and the Ketchikan—will have been issued.

The main object of this publication is to meet the needs of the mining engineers and prospectors, and only so much of the general geology has been incorporated as is necessary to the understanding of the occurrence of the commercially valuable mineral deposits. By this policy it is possible to present some of the economic results of the investigations before the completion of the geologic studies. A more complete exposition of the geology will be presented when the field has been more exhaustively studied.

In such a report only the general features of the occurrence of the ore bodies can be presented. A final analysis of the various problems connected with the genesis and occurrence of the ores must await detailed surveys. Such geologic surveys must be preceded by topographic mapping and hence can be carried on only very slowly. This phase of the work has not been neglected, for two important mining districts, Berners Bay and Kasaan Peninsula, have been mapped topographically, and the latter is being studied by geologists as this paper goes to press.

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[a] Spencer, A. C., The Juneau gold belt, Alaska,: Wright, C. W., A reconnaissance of Admiralty Island, Alaska: Bull. U. S. Geol. Survey No. 287, 1906, 161 pp., 37 pls.

THE KETCHIKAN AND WRANGELL MINING DISTRICTS, ALASKA.

By Fred Eugene Wright and Charles Will Wright.

INTRODUCTION.

GENERAL STATEMENT.

This report deals mainly with the mineral resources of the Ketchikan and Wrangell mining districts, but an introduction, presenting a summary of the general facts so far as known concerning the geology of the region, is necessary. As few detailed studies have been made except those of individual prospects and mines, the work must be regarded as preliminary. Each year since 1904 a summary report [a] of the mining developments and economic resources in the districts has been published; and on account of these publications and the ever-changing conditions of the mines more attention will be given in this paper to the geologic relations and characteristics of the ore deposits than to the details of mining development. Building materials of economic value, including marble, granite, and cement, are also considered briefly, and attention is directed to their increasing commercial importance. This report and the report on the Juneau gold belt by A. C. Spencer [b] complete the preliminary description of the important mining districts of southeastern Alaska. Though the results obtained during the rapid reconnaissance of this large area do not present the refinements of detailed work, it is hoped that their presentation in the following pages will give a fairly correct impression as to the distribution, character, and relative importance of the ore bodies and ore-bearing formations in this section of Alaska.

Both field and office work for this report have been carried on under the direction of Alfred H. Brooks, and to him the writers are greatly indebted for many valuable suggestions; they are also

[a] Bull. U. S. Geol. Survey No. 259, 1905, pp. 47–87; No. 284, 1906, pp. 30–60; No. 314, 1907, pp. 47–81.

[b] Spencer, A. C., The Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 287, 1906.

indebted to E. M. Kindle and G. H. Girty for the study of and the reports on the fossil collections from this area.

The mine owners, operators, and prospectors of the district, without exception, extended to the writers a most cordial cooperation and many courtesies, which are gratefully acknowledged. It is not possible to give the names of all who have aided in this investigation, but the work was especially facilitated by James Bawden, of Ketchikan; U. S. Rush, of Kasaan; B. A. Eardly, of Dolomi; J. L. Parker, of Hadley; William B. Freeburn, of Mount Andrew; Barton B. Neiding, of Niblack; Henry W. Mellen, of Coppermount; Charles A. Sulzer, of Sulzer; W. McLeod, of Dall Island; Charles E. Nassen, of Shakan, and Charles Nelson, of Wrangell.

To W. A. Langille, forest supervisor of the Alexander Archipelago, the writers are indebted for the information regarding the distribution and value of the timber in the region.

FIELD WORK.

The present reconnaissance embraced a land area estimated at 14,500 square miles and includes the portion of the mainland extending from Portland Canal on the south to a line running due east from Cape Fanshaw to the International Boundary, and those islands of the Alexander Archipelago south of Frederick Sound and Sumner Strait. The Ketchikan district to the south is separated from the Wrangell district to the north by a line through Sumner Strait around the north end of Prince of Wales Island, down Clarence Strait as far as Ernest Sound, up Ernest Sound, along Bradfield Canal eastward, and across the mountain range to the International Boundary.

Field work in the Ketchikan district was first undertaken by Brooks in 1901, and the observations included in his report[a] issued the following year were used as a basis for the present investigation.

Field work was begun by the writers May 16, 1905. F. E. Wright started from Ketchikan and made a study of Revillagigedo Island, while C. W. Wright and E. M. Kindle went to Juneau and from there, using a launch, visited the known fossil localities, made collections, and studied the stratigraphic relations on Admiralty, Kuiu, and Kupreanof islands. This work was completed June 20, at which time the writers met at Ketchikan and were joined by Alfred H. Brooks. The entire party then made a study of the geologic section across the Coast Range as exposed from Ketchikan to the head of Portland Canal, and returned to Ketchikan June 30. From July 1 to July 10 Annette Island and a portion of the east coast of Prince of Wales Island were visited. F. E. Wright remained in this region to make detailed investigations of the mining areas, while C. W.

[a] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902.

Wright continued the general geologic mapping around Prince of Wales Island. The latter completed his work and returned to Juneau August 15, and from this date to September 18 was engaged in an investigation of the mines and prospects in the Juneau district.[a] During the latter part of September and until October 20, 1905, he studied the copper deposits in the vicinity of Copper Mountain. F. E. Wright continued his work in the Ketchikan district and on August 31 went north to Wrangell, where he studied the Coast Range belt and ore deposits of the Wrangell district. This work was completed October 10, 1905.

As only three months were devoted to the field work in the Ketchikan and Wrangell districts and as more than half of this time was used at the mines, the geologic mapping had to be pushed forward as rapidly as possible, and many important features were barely touched upon. Nearly 2,000 miles of shore line were hastily traversed, and the geologic mapping was confined principally to the rock exposures along the shores of the island and mainland. These shores are generally rocky, few sand beaches interrupting the continuity of the rock exposures, but, as it was necessary to traverse from 20 to 60 miles of coast line in a day, only the broad geologic features could be noted, and wide areas in the central parts of the island still remain unexplored. This work, especially along the west coast of Prince of Wales Island, was much hampered by the lack of charts, and it was necessary to make a sketch survey of portions of the coast line in conjunction with the geologic mapping.

During the latter part of September, 1906, and the first week of October, after the completion of the season's field work in the Sitka and Skagway districts to the north, C. W. Wright spent three weeks in the Ketchikan district, investigating the mine developments.

MAPS.

The charts of the Coast and Geodetic Survey and the results of reconnaissance surveys from 1890 to 1895 were used as base maps and found to be accurate to the scale. No accurate survey charts along the west coast of Prince of Wales Island and the adjacent islands have been issued, and the published maps of this area were found to be inadequate and had to be supplemented by sketch surveys made by the writers. As the Coast and Geodetic Survey has now begun work in this area, good charts will soon be available. The relief has been mapped in only the eastern part of the province, where topographic surveys have been made by the Canadian Boundary Commission.

Three general maps accompany this volume (Pls. I, II, and III, in pocket). Pl. I, a general map on a scale of about 10 miles to an

[a] Wright, F. E. and C. W., Report on progress of investigations of mineral resources of Alaska: Bull. U. S. Geol. Survey No. 284, 1906, pp. 31–40.

inch, includes both the Ketchikan and Wrangell districts and is compiled from the charts of the Coast and Geodetic Survey, supplemented by sketch maps made by the writers. On this the geology has been represented and also the location of the mines and prospects. The scale of this map is not sufficiently large to include all the names of localities referred to, but these will be found on maps of larger scale. On the other two maps (Pls. II and III), which are contoured sheets of the mainland portion of the province, the geology is plotted in more detail. The contouring of these sheets is taken from the maps of the Canadian Boundary Commission, prepared in 1902 on a scale of 1:160,000, but here reduced to 1:250,000, or about 4 miles to the inch, which is also the scale of the map of the adjacent mainland belt to the north already published.[a] The contour interval is 250 feet, each 1,000-foot contour being emphasized by a heavier line. Sketch maps, introduced throughout the text to show the positions of mining properties, have been furnished for the most part by the mine owners themselves.

LITERATURE.

The first authoritative information in regard to the geology and mineral resources of the Wrangell and Ketchikan districts is the report of W. P. Blake,[b] who made a reconnaissance of the Stikine River in 1863 and whose notes were subsequently published as a Congressional document.

The early explorations of George M. Dawson[c] in 1888 present the first systematic work along the Coast Range in southeastern Alaska. At this time Dawson made geologic sections across the Chilkoot Pass and up Stikine River, and both his maps and geologic records are valuable contributions. In 1891 C. Willard Hayes[d] amplified Dawson's studies of the Coast Range by an intermediate geologic section along Taku Inlet and up Taku River, thus adding largely to our knowledge of the stratigraphy of southeastern Alaska.

The following year investigations were made in the northern portion of southeastern Alaska by H. F. Reid[e] and H. P. Cushing,[f] who made a study of the glaciers and geology of Glacier Bay in 1890–1892,

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[a] See Pl. XXXVII in the Juneau gold belt, Alaska: Bull. U. S. Geol. Survey No. 287, 1906, in pocket.

[b] Blake, W. P., Geographical notes upon Russian America and the Stikine River: House Ex. Doc. No. 177, pt. 2, 40th Cong., 2d sess.

[c] Dawson, G. M., Report on an exploration in the Yukon district and adjacent portions of British Columbia: Geol. Nat. Hist. Survey Canada, vol. 3, pt. 1, 1887–8, pp. 1–277 B; Geological record of the Rocky Mountain region in Canada: Bull. Geol. Soc. America, vol. 12, 1901, pp. 57–92.

[d] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 99–162.

[e] Reid, H. F., Studies of the Muir Glacier: Nat. Geog. Mag., vol. 4, 1892–93; Glacier Bay and its glaciers: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 421–461.

[f] Cushing, H. P., Notes on the geology in the vicinity of Muir Glacier: Nat. Geog. Mag., vol. 4, 1892–93: Notes on the Muir Glacier region and its geology: Am. Geologist, *vol. 8, 1891, pp. 207–230.*

and by William H. Dall[c] and George F. Becker,[b] who visited southern Alaska in 1895 to study its gold and coal resources. They visited a number of localities in the Juneau and Sitka districts and along the coast to the northwest, but at that time practically nothing was known of the mineral resources of the Ketchikan and Wrangell districts.

In the reports of the Harriman Alaska Expedition, which made a cruise along southeastern Alaska and westward in 1899, B. K. Emerson[c] and C. Palache[d] published notes on the lithology and mineralogy of the rocks and ores from various points in southern Alaska.

The most important contribution to the geology of the Ketchikan district and the only extensive report on that area thus far published was made in 1901 by Alfred H. Brooks.[e] The same year Brooks completed a hasty reconnaissance northward as far as Skagway and thence westward to Sitka. In this report not only the areal and structural geology of the Ketchikan district is discussed in considerable detail, but also a geologic correlation of this section with other parts of southeastern Alaska, taken from his data and that of previous investigators, has been included in an introductory sketch of the geology of southeastern Alaska. In 1903 Arthur C. Spencer,[f] assisted by C. W. Wright, made a study of the Juneau gold belt, including the mainland strip from Windham Bay to Berners Bay, and in the same year C. W. Wright made a reconnaissance of the Porcupine district[g] to the northwest. During the years 1904 to 1906 the writers have extended the geologic reconnaissance mapping so as to cover nearly all of southeastern Alaska, and each year a summary report of the results pertaining especially to the economic development of the region has been published.[h] The most complete report on Alaska as a whole is by Alfred H. Brooks,[i] published in 1906. This includes a description of the geography of southeastern Alaska and a correlation of the geology of this section with that of other parts of Alaska and British Columbia.

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[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 763–908.

[b] Becker, G. F., Gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 1–86.

[c] Emerson, B. K., Notes on the stratigraphy of igneous rocks: Harriman Alaska Expedition, vol. 4, 1904, pp. 11–66.

[d] Palache, C., Notes on the minerals collected: Harriman Alaska Expedition, vol. 4 1904, pp. 92–96.

[e] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902.

[f] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906, pp. 1–137.

[g] Wright, C. W., The Porcupine placer district, Alaska: Bull. U. S. Geol. Survey No. 236, 1904.

[h] Wright, F. E., and C. W., Bull. U. S. Geol. Survey No. 259, 1905, pp. 47–68; Bull. U. S. Geol. Survey No. 284, 1906, pp. 30–54, 55–60; Bull. U. S. Geol. Survey No. 314, 1907, pp. 47–72, 73–81.

[i] Brooks, A. H., Geography and geology of Alaska, Prof. Paper U. S. Geol. Survey No. 45, 1906.

HISTORY OF MINING DEVELOPMENTS.

KETCHIKAN MINING DISTRICT.

Prior to the year 1897 the Ketchikan district, which forms the most southern portion of Alaska, had not been investigated, though many prospectors had passed through it on their way north to central Alaska and to the vicinity of Juneau. Moreover, not until 1898 did mining actually begin in the district. During the period of Russian possession of Alaska little or no attempt was made to investigate its mineral resources. Though it seems certain that the Russians had knowledge at least of the existence of some deposits of chalcopyrite ore which form extensive outcrops at tide water in Kasaan Bay, the development of these and other metalliferous deposits was consistently avoided.

Subsequent to the transfer of Alaska to the United States, Charles Baronovich, a Russian merchant, is reported to have located the first copper prospect in the district just south of Kasaan village, where the Copper Queen claim is now located. The comparative isolation of this district and the fact that large bodies of native copper had been found in the Lake Superior region are probably the reasons that these sulphide deposits attracted but little attention.

In the early seventies gold was reported from Unuk River, but the principal gold fields at this period were farther north, at the headwaters of Stikine River and in the Cassiar region, and little attention was given to the Unuk River deposits. During the succeeding years the gold deposits of the northern part of southeastern Alaska at Juneau attracted most of the prospectors, and the Ketchikan district was entirely neglected. Petrof, in the Tenth Census report,[a] mentions a mine which had been opened on Prince of Wales Island and had subsequently been closed. Though he does not give the location of the mine, it is probable that he refers to the early prospects near the present location of the Copper Queen claim, on the north side of Kasaan Bay. Some small shipments of copper ore appear to have been made at this time.[b] In the Eleventh Census report Bruce[c] makes the following statement:

> The indications on the surface are that Prince of Wales Island contains much mineral. Gold, both free milling and in sulphides, silver, galena, copper, and iron have been found in many places, but as yet no extensive efforts have been made to demonstrate whether any of the ores mentioned exist in paying quantities. If minerals exist in other portions of the district, the very limited pros-

[a] Population, industries, and resources of Alaska: Petrof, Ivan, Tenth Census of the United States, 1884, p. 77.

[b] Compare No. 215, Tenth Census of the United States, p. 800.

[c] Bruce, M. W., Population and resources of Alaska: Eleventh Census of the United States, 1890, p. 39.

pecting done has failed to show it. Annette Island may be an exception, and also Dall Island. Some of the finest specimens of gold-bearing ore I have seen in my journey are said to have been taken from Dall Island.

The men engaged in salmon fishing, many of whom had a knowledge of prospecting, were the next to interest themselves in the search for ore bodies in the Ketchikan region. These men explored the coast line and made many locations upon auriferous quartz veins and copper deposits. In the early nineties mining men became interested in these finds and some minor developments were made. Prominent among these men was James Bawden, who discovered in 1892 what he believed to be workable gold deposits on the eastern side of Annette Island.

In 1893 William Barnard relocated the copper prospects just south of Kasaan village and discovered other prospects in the near vicinity. Discoveries on Gravina Island and near Boca de Quadra were made in 1897,[a] and in the succeeding year a number of important locations were made, notably the Gold Standard and other claims on Cleveland Peninsula, the copper prospects at Dall Head on Gravina Island, the gold veins at Dolomi and at Sea Level, and the many discoveries of copper ore on Kasaan Peninsula and on Copper Mountain.

In 1899 discoveries were made at Hollis, at Skowl Arm, and at Niblack Anchorage, and developments were actively advanced at most of the other properties. The two years following were years of great mining excitement in the Ketchikan district, many hundreds of mineral claims were staked, and at a number of localities systematic mining was begun. The developments of this region up to the summer of 1901 are set forth in much detail in the report of A. H. Brooks[b] on the Ketchikan mining district.

Up to this time the Ketchikan mining district was included within the boundaries of the Wrangell recording district, with the recording place at Wrangell. Because of the mining interest in the vicinity of Ketchikan, the United States district court issued the following orders:

Order, that boundaries of the Wrangell recording district No. 1 be so far modified as to exclude from boundaries of said district No. 1 that part thereof as follows:

Beginning at a point on said western boundary line of district No. 1 south of where the same enters Chatham Straits and at a point from which, running due east, will pass the most southern point of Coronation Island 5 miles south of the same, and running northerly along the center of Summer Strait around the most northerly end of Prince of Wales Island to a point where the same joins Clarence Straits and half way between the most westerly point of Zarembo Island and the most easterly point of Point Colpoys on Prince of Wales Island; thence along the center of Ernest Sound; thence running in a northeasterly direc-

[a] Report of the Governor of the District of Alaska, 1897, p. 31.

[b] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902, pp. 35-116.

tion up the center of Ernest Sound and north of Deer Island to the center of Bradfield Canal; thence in an easterly course along Bradfield Canal to the head thereof; then in a due easterly direction to the said International Boundary line; thence along said boundary line in a southeasterly direction through Portland Canal and Portland Inlet to Cape Fox; thence westerly along said boundary line through Dixon's Entrance to a point due south of the center of Chatham Straits; thence due north to the place of beginning.

Further ordered, that area within boundaries thus established be known as the Ketchikan recording district No. 8.

To be in force after December 1, 1901.

Since 1901 rapid progress has been made within the district, and several large new mines have been located and developed to a producing stage. In 1903–4 a 250-ton smelter was erected at Copper Mountain, and in 1905 smelting operations began. At Hadley, on Kasaan Peninsula, a 350-ton smelting plant was built in 1903–4, and here also smelting of the ores began late in 1905. The building of long tramways and wharves at Niblack, Skowl Arm, Karta Bay, Hetta Inlet, and other localities has greatly increased the facilities for mining.

The town of Ketchikan, the official headquarters of the district, is on the west side of Revillagigedo Island and on the east side of Tongass Narrows. It was first located in 1888 as a cannery site with a general trading store, and in 1900 it was incorporated as a town. The town has now a population of about 1,200 and includes two well-equipped hotels and several large outfitting and general trading stores. By steamer route it is 660 miles northwest of Seattle and 240 miles southeast of Juneau. Ketchikan, as it is situated just 60 miles north of the southern boundary line, is the first port of entry and the last port of departure for all vessels engaged in commerce in southeastern Alaska and the commercial distributing point for this portion of the region. It is connected by cable with Seattle and the principal ports in southeastern Alaska. Besides the mining interests there are six salmon canneries, sawmills, and various other industries of commercial importance in the district.

WRANGELL MINING DISTRICT.

Fort Wrangell was established by the Russian-American Fur Company nearly a hundred years ago and received its name from Baron von Wrangell, the second Russian governor. From 1837 to 1847 it was a trading post of the Hudson Bay Trading Company, which still has a station up Stikine River in British Columbia.

Gold was first reported on the bars of Stikine River as far back as 1862, and in 1863, word having been received at Sitka of this discovery, the Russians sent an expedition to Stikine River to find out whether these discoveries were in Russian territory and to establish

the boundary between the Russian and English possessions. W. P. Blake, an American geologist, accompanied this expedition as a volunteer and made notes on the geology of the region and on the occurrence of placer gold, which were subsequently published as a Congressional document.[a] This constitutes the first authoritative information in regard to the mineral resources of southeastern Alaska.

During the early seventies discoveries of placer gold in the Cassiar district of British Columbia attracted hundreds of gold seekers from various countries to Fort Wrangell, whence they journeyed up Stikine River to near its source in the Cassiar district. This, however, was a long and difficult trip, and many of the gold seekers began prospecting in the vicinity of Wrangell, some working northward into the Juneau district. Mineral locations were made in the following years on deposits of gold, copper, and silver-lead ores, but as a whole this section remained comparatively idle until the Klondike excitement in 1897–98. Then Wrangell again became an important transhipment point, because Stikine River became one of the routes to the interior. At this time prospecting was again advanced in the Wrangell district, though with little success. In 1900–1901 considerable work was done on the gold and copper deposits on Woewodski Island by the Olympic Mining Company. A large stamp mill was erected, wharves were built, and other surface improvements were made, but operations were soon suspended. The Wrangell district, though it has not advanced beyond the prospecting stage, contains promising mineral deposits both along the mainland and on the adjacent islands. Several salmon canneries and a large sawmill at Wrangell constitute the principal resources of the district.

The town of Wrangell, with a population of about 1,000, including the natives, is 160 miles south of Juneau, is the distributing point for the Wrangell district, and is also the official headquarters. It is still the supply port for the interior mining camps of British Columbia tributary to Stikine River, and during the summer months a large river steamer makes stated trips between Wrangell and Telegraph Creek, 170 miles up the river.

PRODUCTION.

The following table shows the total metal production for 1905 and 1906 of the ores derived from the copper mines in the Ketchikan district. The second table shows the average content per ton of ore. Outside of the Ketchikan district there are no producing copper mines in southeastern Alaska.

[a] House Ex. Doc. No. 177, pt. 2, 40th Cong., 2d sess.

Total production from copper mines in the Ketchikan district, 1905 and 1906.

Year.	Ore, short tons.	Copper.		Gold.		Silver.		Total value.
		Pounds.	Value.	Ounces.	Value.	Ounces.	Value.	
1905	30,400	1,901,392	$295,616	1,178	$34,370	13,000	$7,867	$337,853
1906	85,139	4,350,571	838,000	3,031	62,851	27,152	18,102	919,613

Average content per ton of ore from copper mines in the Ketchikan district, 1905 and 1906.

Year.	Copper.		Gold.		Silver.		Total value.
	Pounds.	Value.	Ounces.	Value.	Ounces.	Value.	
1905	62.5	$9.75	0.038	$0.78	0.43	$0.26	$10.79
1906	51.1	9.86	.036	.74	.32	.21	10.81

In computing the value of the metal content of the ores the average values of silver and copper in 1905 and 1906 were taken, as follows: For 1905, silver=$0.604 per ounce, copper=0.156 per pound; for 1906, silver=$0.67 per ounce, copper=$0.193 per pound.

The total copper production of the district previous to 1905 is estimated at 1,600,000 pounds. At 12 cents per pound, the average price of copper for that period, the value of this is $192,000. These amounts added to those for 1905 and 1906 give a total copper production of 6,251,963 pounds and a total value of $1,134,276.

The remarkable increase noted in the preceding tables from the mines in the Ketchikan district has brought this section of Alaska well to the front as a copper-producing region. Practically the first large shipments were made in the spring of 1905, and since that time the production has steadily increased. The rise in the price of copper from an average of $0.156 a pound in 1905 to an average of $0.193 a pound in 1906 has permitted the profitable extraction of copper ores of lower grade than those mined in 1905, and by the improvement in transportation and mining conditions it will be possible to mine ores still lower in metal content. In 1906 there were 10 producing copper mines in the districts, whereas in 1905 only 6 were productive.

There are only a few gold mines in the Ketchikan and Wrangell districts and their output has been spasmodic. During 1906 only two gold mines were productive, though from several others there was a considerable output in previous years. Brooks estimated the total gold output in 1901 to be $100,000. From 1901 to the end of 1906 the production from the gold mines is estimated at $120,000. These amounts added to the gold production from the copper ores, which is approximately $110,000, gives a total gold output of $330,000. The silver production is estimated at $30,000 from the copper ores, $16,000 from the gold ores, and about $4,000 from the silver-lead ores.

GEOGRAPHIC SKETCH OF SOUTHEASTERN ALASKA.

Southeastern Alaska embraces an area of high relief, whose dominating feature is the Coast Range skirting the mainland on the east (Pl. IV). To the west it includes Alexander Archipelago, with its maze of waterways and numerous islands. These islands are also of high relief, but in general the uplands fall off toward the Pacific. The Pacific Mountain system as defined by Brooks[a] embraces a broad zone of ranges lying parallel to the southern coast line of Alaska and forming with it a curve concave toward the south. Of these the Coast Range, the St. Elias Range, and the Aleutian Range lie adjacent to the coast, while the Alaska Range is inland and forms the northern border of the system. In southeastern Alaska the system includes the Coast Range and the seaward group of mountainous islands of Alexander Archipelago. The same general subdivision into a mainland Coast Range and an outlying mountainous belt, called the Vancouver Range by G. M. Dawson,[b] continues into British Columbia, where it is more sharply marked. The Coast Range extends from southern British Columbia into southeastern Alaska, where it lies partly in Alaska and partly in Canada. To the northwest it passes inland behind the St. Elias Range and thence decreases in altitude, gradually merging into the interior plateau. A remarkable feature of this range, which was noted by Dawson[c] and Hayes,[d] is the uniformity of the summit levels, which present the appearance of a dissected plateau.

The mountain masses composing the outlying islands of southeastern Alaska, though separated from the St. Elias Range on the north by Cross Sound and not orographically connected, are geologically similar and, as suggested by Brooks,[e] may properly be considered the southeastern extension of the St. Elias Range (Pl. IV).

From Dixon Entrance, the southern limit of Alaska, to Cross Sound, a distance of 500 miles, the islands and mainland are broken by an intricate system of waterways and fiords. Some of these reach far inland, but they frequently run parallel with the coast. Chatham Strait, with its northern extension, Lynn Canal, is the longest fiord. It passes over three degrees of latitude, a distance of 250 miles, and is from 3 to 6 miles broad with a depth of from 1,000 to 2,500 feet. This fiord traverses the general trend of the mountain ranges and the bedrock structure at an angle of about 30° and in this differs from

[a] Brooks, A. H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey, No. 45, 1906, p. 28.

[b] Trans. Roy. Soc. Canada, vol. 8, sec. 4, 1890, p. 4.

[c] Dawson, G. M., Report on the area of the Kamloops map sheet, British Columbia: Ann. Rept. Geol. Survey Canada, new ser., vol. 7, 1894, p. 10 B.

[d] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 4–24.

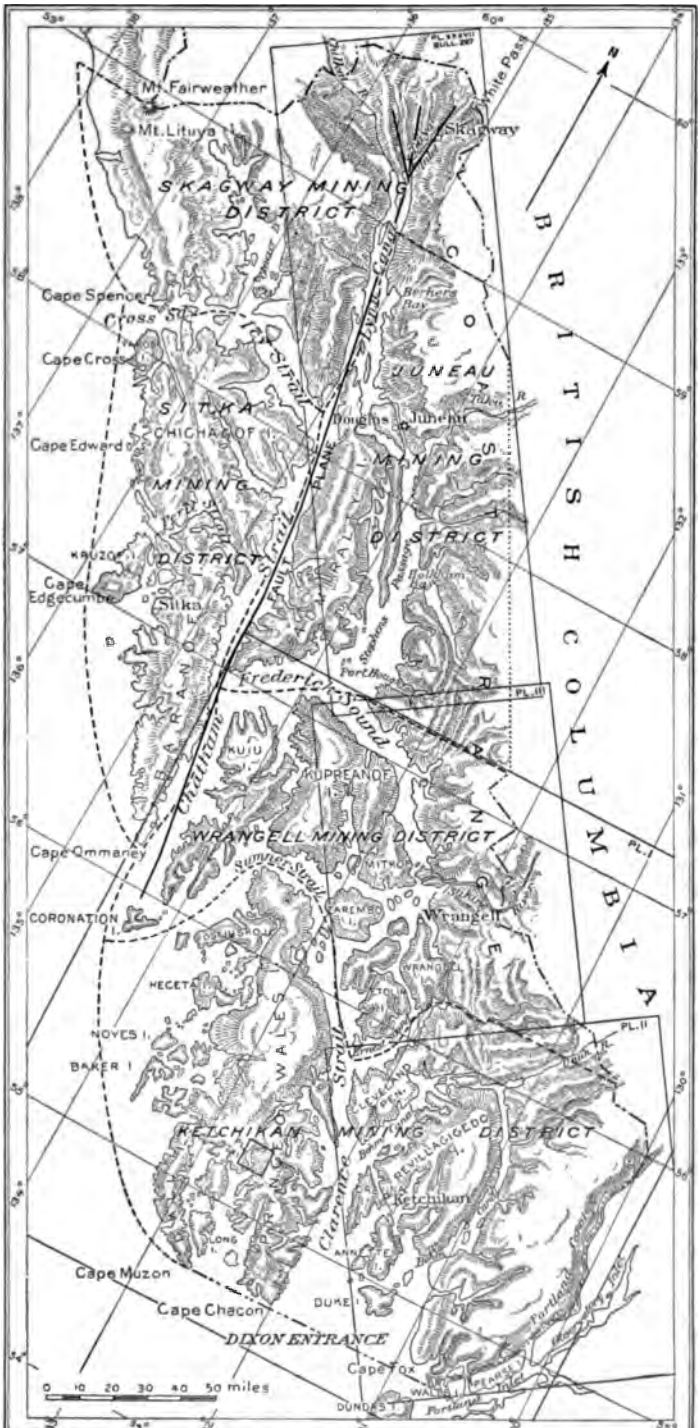
[e] Op. cit., p. 29.

the other watercourses, which are either parallel to the coast line and trend of the rock beds or cut across them irregularly at much greater angles. Both the geology and the topography indicate that the position of Lynn Canal and its southern extension, Chatham Strait, is determined by a line of faulting (Pl. IV). Other important fiords are Portland Canal (Pl. V, A), Clarence Strait, Behm Canal, Taku Inlet, and Glacier Bay, each of which has its own characteristics. These waterways, which are long, narrow, deep arms of the sea extending far back into the mountains, have been aptly compared with wide, slowly flowing rivers. The flow varies with the tide, the rise and fall averaging about 15 feet and causing strong eddies and currents between periods of high and low water. In southeastern Alaska these inland passages are known locally not as fiords but as canals, straits, inlets, coves, bays, sounds, and arms. They are a distinctive and dominating feature of the country and furnish both effective and safe routes of communication between different points of a region which is otherwise mountainous and difficult of access. The topography is so rough and uneven that only at great expense and in favored localities can even wagon roads be constructed and railroads of any length can hardly be considered. The fiords, however, not only are of the greatest value as highways of commerce, but possess a great commercial asset in the immense quantities of fish, especially salmon, halibut, and herring, which throng their waters at different seasons of the year. The ease with which transportation can be effected is also an important factor in mining operations and the lumber industry.

GEOGRAPHY OF THE KETCHIKAN AND WRANGELL DISTRICTS.

GENERAL STATEMENT.

The area considered in the present report, the Ketchikan and Wrangell districts, is located at the southern end of the Alaska panhandle; it begins at Portland Canal and is limited on the north by Frederick Sound. Its total land area approximates 14,500 square miles, about one-third of which is included in islands. Of these Prince of Wales Island is the largest, and Revillagigedo, Kupreanof, and Kuiu islands are next in size.



GENERAL MAP OF SOUTHEASTERN ALASKA.

Showing *mining districts* and *areas covered* by geologic maps in this report.

In the following table an estimate is given of the area of the mainland and of the larger islands in each district:

Areas of the Ketchikan and Wrangell districts.

	Square miles	
Ketchikan district:		
Mainland	4,050	
Islands over 100 square miles in area:		
Prince of Wales Island	2,800	
Revillagigedo Island	1,120	
Gravina Island	102	
Annette Island	133	
Dall Island	275	
Kosciusko Island	160	
Total of islands less than 100 square miles in area	730	
		9,370
Wrangell district:		
Mainland	2,200	
Islands over 100 square miles in area:		
Kupreanof Island	1,080	
Kuiu Island	750	
Mitkof Island	200	
Wrangell Island	220	
Etolin Island	330	
Zarembo Island	180	
Total of islands less than 100 square miles in area	170	
		5,130
Grand total		14,500

MAINLAND BELT.

The mainland belt includes the mainland area and the islands which lie east of a line extending from Dixon Entrance through Clarence Strait and Duncan Canal to Frederick Sound. In general aspect the topographic character of this eastern portion differs but little from that of the other portions of the Coast Range province to the north and south. The mountains rise abruptly, at some places in sheer cliffs, from tide water to elevations of 2,000 to 5,000 feet, and the peaks farther inland reach altitudes of 6,000 to 10,000 feet. These mountain masses are made up essentially of the immense batholiths of the Coast Range granite,[a] and the land features are chiseled on a correspondingly broad scale. Owing to the mode of formation and physiographic development of these mountains, there is frequently a decided lack of bed-rock control of the lines of drainage or erosion. Though profoundly dissected, the mountains show a notable tendency to uniformity of elevation in the crest lines of their summits (Pl. V, *A*). These summits are usually broad and somewhat flat with gently arched backs, and if the intervening precipitous valleys were

[a] See p. 61.

filled to their original profiles, there would be an undulating and warped surface sloping gradually seaward from the center of the range.

The land forms over the entire area indicate an intensely glaciated region which has been but slightly modified by water erosion since the glacial epoch. At the time of the maximum ice flooding, during the glacial epoch, the ice sheet covered the whole area with the exception of isolated high peaks which can be recognized at present by their sharp, serrated outlines and lack of glacial rounding. Even at the present time of glacial drought a number of small ice fields are still within the Coast Range belt of this area, located above snow line and sending small tongues down the valleys even to tide water. The special features of glacial sculpture, as U-shaped valleys, fiords, glacial erratics, cirques, hanging valleys, double cliff slopes, truncation of spurs and tendency toward perfect alignment of cliff bases, glacial grooves and striæ, and *roches moutonnées*, are developed to a remarkable degree within this area. The noticeable absence of moraines in such an area of extensive glaciation is due chiefly to the peculiar steepness of the mountain and valley slopes. Many of the fiords are floored by sand and gravel moraines and are frequently partially choked at their entrances by morainal material. Among the higher mountains inland small glaciers are present, and in Le Conte and Thomas bays they extend to tide water, but none were observed on the adjacent islands.

Forelands occur locally (Pl. V, *A*), but are of small extent, and the only large areas of level land in the region are at the mouths of the greater watercourses, notably at the mouth of Stikine River, where the counteraction of the tide and stream flow has caused the deposition of sands and muds and formed broad tide flats.

Peninsulas and islands adjacent to the mainland are separated by deep, narrow fiords extending many miles inland. Cleveland Peninsula, the largest of these promontories, is 10 to 15 miles wide and contains mountains whose summits reach over 4,000 feet in elevation. Revillagigedo Island is separated from the mainland by Behm Canal, a narrow, steep-sided fiord, which surrounds the eastern half. Its mountain tops range from 2,000 to 4,000 feet above sea level. George and Carroll inlets and Thorne Arm dissect this island and border narrow promontories whose altitudes reach about 3,000 feet.

The mainland belt is intricately dissected by narrow steep-sided valleys heading in mountainous canyons, many of which are filled with snow, or in glacial cirques, many of which contain small glaciers or patches of ice. The initial descent of these valleys is steep, the streams often forming beautiful waterfalls of great volume and power. Tributary creeks or rivers enter from both sides, the valleys gradually widen, and the valley floors become covered with a gravel

A. VIEW FROM BOUNDARY PEAK DOWN PORTLAND CANAL.

Showing abrupt topographic relief.

B. VIEW FROM MOUNT ANVIL, ANNETTE ISLAND, NORTH TOWARD KETCHIKAN.

Showing forelands and topographic sculpture of the islands adjacent to the mainland.

wash consisting largely of gravel, cobbles, and bowlders of granite. As the grade decreases the gravel beds become deeper and wider and the stream flows around the flanks of precipitous mountain spurs and enters the sea at the head of some tidewater inlet. The tide flats at these points are usually wide and are composed of fine sand and mud, the depth to bed rock being probably several hundred feet. They extend into the channels for a short distance beyond the low-tide line and there end abruptly. Depths of 50 to 100 fathoms are common in these inlets a short distance from the shore.

The largest of these valleys is that of Stikine River (Pl. VI), which rises in British Columbia, crosses the Coast Range mountain divide, and forms a drainage valley for part of the inland plateau. Its numerous branches interlock (1) with the headwaters of Taku River; (2) with the streams flowing into the Yukon to the northeast; (3) with the streams tributary to Dease Lake and Dease River to the northwest, a part of the McKenzie River drainage; and (4) with the streams flowing south into Nass River. The upper valley of Stikine River, which here flows in a southwesterly direction, is broad and slopes at low angles. It changes, however, to a canyon as it begins to traverse the Coast Range, and in Kloochman and Little canyons steep cliffs rise abruptly 1,000 feet or more on each side. Below Kloochman Canyon the river changes its course from a southwesterly to a general southerly direction, and 20 miles from its mouth it bends sharply to the west. Throughout its course in the mountains the effects of ice sculpture are visible and dominate the landscape. Several large glaciers, notably Flood Glacier, Dirt Glacier, Great Glacier, and Popof Glacier, still occupy tributary valleys and can be observed from the main valley. Stikine River reaches salt water at the head of Stikine Sound, 12 miles north of Wrangell, where a wide delta has been formed.

Among other river valleys are those of the Unuk and Chickamin, both large rivers and next in size to the Stikine. Their source, however, is on the western slope of the mountain divide and their valleys are more or less canyonlike to the sea, a distance of less than 60 miles.

The seaward extension of many of these valleys is represented by tide-water channels or fiords. The largest of these in this region is Portland Canal, which extends inland 150 miles, with an easterly and then northerly course (Pl. V, A). It is only a mile or two in width, from 100 to 200 fathoms deep, and the mountains rise to elevations of 4,000 to 6,000 feet a short distance inland from its sides. Bear and Salmon rivers enter at the head of this canal. Next in size is Behm Canal, which branches west and south from the mouth of Unuk River. The southern branch is much broader than Portland Canal, and several smaller river valleys and inlets are tributary to it from the east, as Smeaton Bay, Rudyerd Bay, Walker Cove, and Chickamin

River. The west branch of Behm Canal is narrow at first, then it takes a southwesterly course and widens into a sound with many bays entering it. Among the smaller canals are Willard Inlet, Nakat Inlet, Boca de Quadra, and Bradfield Canal on the mainland, and Thorne Arm, Carroll Inlet and George Inlet on Revillagigedo Island.

SEAWARD ISLANDS.

There are no topographic maps of Prince of Wales, Kuiu, or Kupreanof islands, and little is known in detail of their valley courses or the trend of their mountain ranges. The shore line has been carefully mapped along the eastern portions of these islands, but much remains to be accomplished along the western coast, notably on Prince of Wales and Kuiu islands.

Prince of Wales Island is 80 miles long and 30 miles wide; its shore line is indented by numerous bays and inlets, which are characteristic of the entire coast. It is separated from the mainland by Clarence Strait, a deep channel about 4 miles wide, running north and south. Portions of the west coast are directly exposed to the Pacific Ocean, but most of it is protected by the small seaward islands, the largest of which is Dall Island. Viewed from the channels, Prince of Wales Island presents a mountainous mass of very irregular outline. Its relief, however, is less rugged than that of the mainland or of some of the islands to the north, such as Baranof Island. A low pass across the island, 4 miles long and less than 150 feet in elevation, connects the head of Cholmondeley Sound on the east with the head of Hetta Inlet on the west coast. Another pass, 6 miles long, unites the south arm of Cholmondeley Sound with Klakas Inlet. The head of Twelvemile Arm also is connected with Big Harbor on the west coast by a portage several miles long. Numerous lakes occur inland both in low-lying valleys and in basins from 1,000 to 2,000 feet in elevation. The mountain summits range in height from 2,000 to over 3,000 feet, the highest being Copper Mountain, 3,800 feet above sea level.

Still less is known of Kupreanof Island. On its north end are two small mountain ranges: the one northeast of Kake village has summits reaching altitudes of 3,000 feet, and the other, the Bohemian Range, just west of Portage Bay, includes peaks 2,500 feet in elevation. The southern end of the island consists of low-lying hills rarely exceeding 1,000 feet in altitude. A low pass from the head of Duncan Canal to Portage Bay nearly separates the eastern from the western half of the island.

Kupreanof is separated from Kuiu Island by Keku Strait, an irregular tide-water passage, through which only small boats can pass. Kuiu Island is deeply dissected by bays, which almost divide it and give it an extremely irregular shore line. At the head of Bay

KLOOCHMAN CANYON, STIKINE RIVER.

View northeast toward the eastern contact of the Coast Range intrusives. In the distance is a black band of argillites dipping away from the granite intrusive and overlain by a white band of limestone.

of Pillars is a portage 1 mile in length, which connects with Port Camden on the east side of the island. Another low pass extends from the head of Port Camden to Threemile Arm on the southeast side of the island. Small mountainous areas were noted on the west coast of Kuiu Island east of Washington Bay and on the two peninsulas forming the south end of the island. Few of the highest peaks exceed 2,500 feet in elevation, and the mountain summits are generally less than 2,000 feet.

In general both the course of the valleys and the trend of the small mountain ranges of these outer islands conform to the underlying rock structure, which has largely controlled the erosive processes. The intrusive masses and upturned edges of resistant schists and limestones persist above the general level and form the hills, ridges, and mountain peaks. The areas of soft shales, sandstones, and less resistant rocks are marked by lowlands, deep valleys, and channels.

No glaciers or ice fields are now on these islands, but evidence of former glaciation is everywhere present. On Prince of Wales Island basins scooped by glacial action and now filled with lakes occur at elevations of 600 to 2,000 feet in the vicinity of Copper Mountain, and the surrounding mountains, composed essentially of granite, are well rounded and have on them many large bowlders which are evidently erratics. In the Klawak Range to the north are several clearly defined glacial cirques containing small lakes and surrounded by more or less jagged crest lines. In the rock exposures along the tide-water channels grooves were observed in a few places which may also be attributed to glaciation. Similar phenomena were noted on Kuiu and Kupreanof islands.

The coast line of these islands is broken by bays, coves, and channels. The hydrographic maps of this area show numerous excellent harbors and many protected channels which favor navigation. One of the striking features is the shallowness of many of the bays and channels as compared with the depths noted in the fiords of the mainland belt. Again, the river deposits at the heads of bays have a gradual slope and do not descend abruptly into deep water a short distance from the shore, as do the tide flats along the mainland. These facts and the topographic observations tend to show the greater advance in topographic development of the seaward portion in contrast with that of the mainland. (Compare Pl. V, *A*, with Pl. V, *B*.)

CLIMATIC CONDITIONS.

The annual changes in climatic conditions in southeastern Alaska are not so varied as might be expected for a region lying between 55° and 60° north latitude. The effect of the warm ocean current of the northern Pacific is strongly felt and serves to moderate the climate.

This region is characterized by mild winters and cool summers, and by heavy precipitation, which is greatest at the points exposed to the sea and diminishes somewhat inland. Nearly all the precipitation below an elevation of 500 feet is in the form of rain. Most of the rain falls between the first of September and the last of January, though the amount varies greatly from one year to another. The season of least rainfall is generally from April to July.

The prevailing winds come from the southwest, and bear humid atmosphere from the sea, which gathers about the mountain range and condenses in the form of fog and rain. This causes excessive rainfall along the western slopes of the Coast Range, while the inland regions to the east suffer for want of the rains thus intercepted. A change from a southwest to a north wind almost invariably brings fair weather.

The temperature throughout the year is mild, the thermometer rarely falling to zero Fahrenheit at the lower elevations. The snowfall is heavy in the mountains, from 3 to 8 feet in depth, but near sea level not more than a few inches of snow fall at one time during an ordinary winter and this soon disappears.

Two tables from a report on the meteorology compiled by Cleveland Abbe, jr.,[a] follow, one presenting the average rainfall per month in inches at different points along the coast, the numbers representing the mean precipitation for two or more years; the other giving the average maximum and minimum temperature in degrees Fahrenheit for each month, as recorded at the different stations for periods of several years. A third table, compiled by Alfred H. Brooks, is added for the purpose of comparison. It gives the average monthly temperatures at various stations in southeastern Alaska and at foreign localities of about the same latitude. The data from the station at Port Angeles in Washington is included with the others to show the slight difference that exists between the average monthly temperature in southeastern Alaska and that of the portion of Washington adjacent to the coast.

Average monthly precipitation in southeastern Alaska.

[In inches.]

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Wrangell	6.07	8.11	2.89	4.11	3.71	3.56	3.69	3.07	6.63	7.36	11.27	10.41	70.88
Killisnoo	5.98	4.96	4.04	3.50	3.58	2.36	4.19	4.00	7.79	7.92	5.16	4.81	58.97
Juneau	8.77	4.38	4.62	7.04	4.28	3.09	3.96	9.39	11.39	11.47	7.51	8.37	84.27
Skagway	.90	.57	.64	2.39	.77	.60	1.73	1.51	3.47	3.22	3.22	3.78	21.75
Sitka	12.17	7.47	6.70	5.61	4.11	3.31	3.55	5.84	9.67	11.96	9.80	7.88	88.10

[a] Prof. Paper U. S. Geol. Survey No. 45, 1906, pp. 158–167.

Monthly maximum and minimum temperatures in southeastern Alaska.

[In degrees Fahrenheit.]

Station.	Jan.		Feb.		Mar.		Apr.		May.		June.	
Wrangell	47	-4	58	2	54	-10	64	24	78	38	85	38
Killisnoo	52	-2	50	-10	52	-2	63	15	76	24	76	33
Juneau	44	4	50	4	61	-5	61	28	69	29	80	36
Skagway	42	-4	44	-9	63	-10	61	16	79	25	90	31
Sitka	51	-2	54	-3	65	-1	70	19	80	28	80	33

Station.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
Wrangell	82	44	84	43	73	38	67	31	53	4	52	-3
Killisnoo	84	38	81	36	69	27	60	25	53	1	54	1
Juneau	86	40	71	39	65	34	65	23	56	10	54	8
Skagway	92	39	90	32	76	30	60	16	51	7	57	-4
Sitka	87	35	82	39	74	32	65	25	59	5	59	7

Mean monthly temperatures for stations in southeastern Alaska and for foreign localities near the same latitude.[a]

[In degrees Fahrenheit.]

Station.	Latitude.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.
	°	′							
Wrangell	56	33	26.2	30.8	31.6	42.7	49.3	55.3	58.2
Sitka	57	3	32.9	33.6	37.1	42.1	47.6	51.9	55.1
Juneau	58	18	27.5	24.7	33.5	40.1	47.6	53.6	56.6
Killisnoo	57	28	27.7	26.8	33.1	36.9	45.6	51.6	55.2
Port Angeles, Wash	48	10	34.7	36.7	41.7	45.6	50.6	54.0	56.6
Christiania, Norway	60		24.1	23.9	29.5	39.9	50.9	59.9	62.6
Helsingfors, Finland	60	20	20.9	18.8	26.2	34.8	44.1	56.9	61.9
Stockholm, Sweden	59		33.5	29.5	33.8	39.5	52.5	57.0	59.1
Scotland	57	30	37.1	38.4	39.5	44.1	49.0	54.8	57.1

Station.	Latitude.		Aug.	Sept.	Oct.	Nov.	Dec.	Average.
	°	′						
Wrangell	56	33	57.5	52.3	45.9	33.5	32.9	43.0
Sitka	57	3	56.4	52.3	46.2	38.9	35.8	44.2
Juneau	58	18	55.0	49.9	41.9	31.2	29.3	40.9
Killisnoo	57	28	54.4	47.8	41.1	33.4	30.1	40.3
Port Angeles, Wash	48	10	56.8	52.7	47.7	42.4	28.2	46.1
Christiania, Norway	60		60.6	52.7	41.9	32.1	25.0	41.9
Helsingfors, Finland	60	20	58.3	50.5	43.9	33.7	21.7	39.2
Stockholm, Sweden	59		59.3	53.6	40.6	35.6	27.3	43.4
Scotland	57	30	56.6	52.8	46.4	40.6	37.8	46.1

[a] Compiled by Alfred H. Brooks from the following publications: U. S. Weather Bureau reports; Landrugsdirekt, Beretning, 1893; Pfver, Finska Vetenskaps Soc. Forhandlinger; Meteror Iaktag. I Sverige k. Svensk Vetens. Akad., 1890; Trans. Highland and Agric. Soc. Scotland, 1895.

These tables show that climatic conditions in the Ketchikan and Wrangell districts are favorable for the development of mining enterprises. The abundant precipitation is rather trying to those who are accustomed to a more arid climate, but this rainfall, though a drawback to the prospector, does not interfere with mining developments. In fact, it is an advantage, as it furnishes considerable water power which can be utilized in mining operations. Except at high altitudes, snow does not interfere materially with transportation or mining.

TIMBER AND VEGETATION.

DISTRIBUTION OF TIMBER.[a]

Southeastern Alaska is mostly forested, but the portion covered with a commercial stand (marketable timber) is relatively small. The greater part is included in the Alexander Archipelago National Forest.

The forests of the region are made up of the coniferous species shown in the following list, which presents also an estimate of the approximate quantity of each:

Trees of southeastern Alaska.

	Per cent.
Western hemlock, *Tsuga heterophylla*	60 to 70
Sitka spruce, *Picea sitchensis*	20 to 25
Yellow cedar, *Chamæcyparis nootkaensis*; Red cedar, *Thuya plicata*; Alpine hemlock, *Tsuga mertensiana*; Jack pine, *Pinus contorta*	15 to 25

The amount of timber in the stands of commercial forests varies greatly, ranging from 30,000 to 80,000 feet (board measure) per acre. The average stand of saw timber along this coast, however, is much less, probably not more than 5,000 to 10,000 feet per acre, because of the wide intervals of poor forest growth in the swampy areas and on the higher slopes.

Except on the limited areas of alluvial deposits along the streams, the logging conditions are not good, the best timber being on steep or rough ground.

Although the hemlock is the dominant tree and the best timber for general purposes, it is little used for saw timber because of a public prejudice against it. Loggers often object to cutting it because its excessive weight adds to the difficulty of towing. It is used at present chiefly for piling, for which it is well adapted if cut during the winter months, when the bark is close and not so susceptible to the attacks of the ship worm (*Toredo navalis*). The tree of greatest present commercial value is the spruce, which is used for all purposes. Its soft, fibrous wood has little shearing strength and is not serviceable for ore bunkers, bins, or other structures requiring great strength. Many spruce trees have magnificent proportions, and the average yield of lumber for each tree is from 3,000 to 4,000 feet.

The supply of standard spruce logs available by beach hand logging has now nearly been exhausted, so that the use of hemlock is increasing and mine operators are getting a stronger, better timber.

[a] For the notes on distribution and value of timber in southeastern Alaska the writers are indebted to Mr. W. A. Langille, forest supervisor at Ketchikan, Alaska.

The red cedar, being near its northern limit of growth, is not of the best quality, and the hand loggers do not go far enough inland to obtain the best growth. It is therefore little used except for boat building.

Yellow cedar of good quality occurs too far inland and at altitudes too high above sea level to be obtained by the present methods of logging. Trees of good size and fairly clear are found, yielding an excellent finish material susceptible of a high polish, but there is little demand for it in this region.

VALUE OF TIMBER.

The abundance of the timber supply of Washington and Oregon and its nearness to comparatively inexpensive means of transportation precludes for some time the probability of considerable demand for the timber of this region.

The present low price of lumber of the quality used in southeastern Alaska renders competition between the two regions impossible except for local requirements. Logging operations are successful close to tide water, where the position of the timber permits easy transportation. The requirements necessarily imposed on timber cutting within the reserves, by which only a certain percentage of the forest may be removed, the care necessary to avoid injury to the remaining trees, and the expense involved in disposing of tops and litter so increase the cost that logging on a large scale with the view of shipping from Alaska appears at present unprofitable.

In southeastern Alaska as a whole the quantity of first-class timber is limited, though the region possesses many million feet of an inferior grade, suitable for rough material and pulp wood, which may some day be a considerable resource.

GROWTH OF VEGETATION.

The luxuriant growth of vegetation along the coast of southeastern Alaska may well be compared with that of a tropical region. This is caused by the moist and temperate climate and the long summer days at this high altitude. At elevations below 1,500 feet bushes, ferns, and tall grasses grow profusely, especially in the valleys and gulches. These form in places a dense and almost impassable undergrowth and are a great hindrance to the prospector. Among the most common of these shrubs are the thorny devil's club, the salmon berry, the elderberry, the huckleberry, the high bush cranberry, various willows, the black alder, and the white alder, the latter forming thickets along the streams and mud flats.

THE NATIONAL FOREST.

The Government has wisely added several of the large islands, namely Prince of Wales, Kuiu, Kupreanof, Zarembo, and Chichagof islands of the Alexander Archipelago, to its national forest, thereby insuring intelligent use of the timber for the present and preservation and protection for future demands. Though the establishment of the new Alexander Archipelago National Forest appears to many in Alaska to have placed a restraint on the prospector and mine owner, yet the provisions of the law in regard to mining within the reservation are liberal. The following extracts from the "Use Book" relate to the Alaskan national forests:

REG. 36. Trails on national forest lands in Alaska may be constructed, extended, or repaired without permit. Wagon roads may be constructed, widened, extended, or repaired when needed, but permit must first be obtained from the supervisor. Permits will not give any right to the exclusive use, or to charge toll, or against future disposal of the land by the United States.

REG. 37. When a right of way or other special use is granted within a national forest in Alaska, the supervisor may, without charge, allow the cutting of timber when this is necessary for the proper enjoyment of the special use.

REG. 38. Without permit, and free of charge, settlers, farmers, prospectors, fishermen, or similar persons residing within or adjacent to national forests in Alaska are granted the privilege of taking green or dry timber from the forests, and driftwood, afloat or on the beaches, for their own personal use, but not for sale; provided that the amount of material so taken shall not in any one year exceed 20,000 feet board measure, or 25 cords of wood; and provided further, that the persons enjoying this privilege will, on demand, forward to the supervisor a statement of the quality of the material so taken and a description of the section from which it was removed.

It is also to be noted that timber cut from the national forest in Alaska may be exported from the district and sold in any market anywhere, upon certification by the supervisor that the timber has been purchased and cut from the national forest in Alaska. The exportation of timber from all areas in Alaska not included in the forest reserve is prohibited by law.

GENERAL GEOLOGY OF SOUTHEASTERN ALASKA

GENERAL STATEMENT.

The geologic distribution of the rocks along the southeast coast of Alaska is on a broad scale, and in their strike they follow the general northwest trend of the mountain range. These rocks may be divided into two main groups: (1) Stratified rocks, and (2) intrusive rocks, both having about the same areal extent.

The term "stratified rocks" has been used to include those formed (1) by sedimentation, such as shales, sandstones, conglomerates; (2) by precipitation and sedimentation, as limestones and cherts, and (3) by volcanic activity, as the lava and tuff beds. These beds occur

interstratified with one another and, except the more recently formed rocks, are generally intricately folded and usually show a high degree of metamorphism. In this altered state they are represented by black slates, crystalline schists, graywackes, crystalline limestones, quartzites, and chlorite and amphibole schists.

The intrusive rocks are made up of a complex of coarse granular rocks, mostly granitic in character. They form the great mass of the Coast Range bordering the mainland, and occupy wide areas in the central portions of many of the islands. Their mode of occurrence is at many places directly related to the geologic structure, and their longitudinal axes and lines of contact are usually parallel with the strike of the bedded rocks.

STRATIGRAPHIC SUCCESSION.

The geologic succession of the stratified rocks in southeastern Alaska is complex, and includes rock formations representing nearly all the geologic periods from early Paleozoic to the present. Though the rocks have been mapped only in a broad way, the sequence of the formations has been sufficiently well established to permit grouping them according to age. The stratigraphic succession is presented in the table on pages 34, 35, and in this an attempt has been made to show not only the general order of rock deposition but the relations of the strata of the different periods, so far as known, and their structural characteristics.

Stratigraphic column in southeastern Alaska.

Age.	Thickness (feet).	Character of rocks.	Structural characteristics.	Localities of occurrence.
Recent	500±	Basaltic lavas, tuffs	Flat lying, undulating	Mount Edgecumbe, mainland, Ketchikan district.
		Unconformity.		
Pleistocene	(?)	Gravel bench deposits interstratified with clayey beds carrying marine shells.	Flat lying, cross-bedded	Douglas Island, Funter Bay, Port Snettisham.
		(?)		
Pliocene	1,000±	Conglomerates, sandstones, shales, coal seams, containing marine shells and fossil plants.	Faulted and tilted at low angles.	Lituya Bay, Icy Point.
		(?)		
Eocene to Upper Cretaceous.	1,500±	Basalts, andesites, rhyolite tuffs, breccias, conglomerates, sandstones, and coal seams, with fossil plants.	Flat lying, slightly tilted, covering wide areas.	South end Kupreanof Island, Port Camden, Hamilton Bay, Murder Cove, Kootznahoo Inlet.
		Conformity.		
	1,000+	Conglomerates, sandstone, shale, and coal seams, with fossil plants	Tilted, slightly folded, unmetamorphosed, occupying local basins.	
		Unconformity.		
Lower Cretaceous to Jurassic.	500+	Shale, conglomerate, and black limestone with fossils	Folded and faulted, with steep dips and variable strikes, slightly metamorphosed, occurrence local.	Pybus Bay, Admiralty Island.
		Conformity.		
	200+	Gray limestone, *Aucella* beds	Same as above.	
		(?)		
	2,000±	Graywackes, slates, and conglomerates, carrying granite cobbles; lava conglomerates, and sandstones; no fossils.	Folded and faulted, indurated, variable strike and dip, distribution limited.	San Fernando Island, west coast of Prince of Wales, Uolla Channel.
		Conformity.		
	1,000±	Andesitic lavas, tuffs, breccia, conglomerate, and sandstone overlying granite intrusives; no fossils.	Steeply tilted and folded with general northwesterly strike and variable dip, metamorphosed and rendered slightly schistose; distribution limited.	South end Prince of Wales Island, Klakas Inlet.
		(?)		
Triassic	(?)	Gray argillaceous limestone, fossiliferous, calcareous sandstone, conglomerate.	(?)	Hamilton Bay, Screen Islands.
		(?)		
Permian (upper Carboniferous).	1,000±	Cherty limestone breccia and conglomerate, carrying fossils	Steeply tilted and folded, metamorphosed.	Hamilton Bay, Screen Islands, Pybus Bay.
		(?)		
	800+	White cherty semicrystalline limestone, fossiliferous	Strike variable, steeply tilted, broadly folded, metamorphosed.	Pybus Bay, Herring Bay, Screen Islands, Pybus Bay.
		Conformity.		
	100+	Conglomerate; no fossils; same as above		

		(?)		
Probably Permian (upper Carboniferous).	3,000±	Slates, graywackes, and conglomerates; no fossils	Folded, highly tilted, schistose and indurated, finely bedded; strike northwest, widely distributed.	Sitka, Cape Edward, Douglas Island, Glass Peninsula.
		Unconformity.		
Permian to Pennsylvanian (upper Carboniferous).	4,000±	Slates, greenstones, lavas, agglomerates, tuffs, and breccias, intermixed with argillaceous graphitic slates and schists; metamorphosed and interfolded in bed-rock complex; no fossils.	Folded with general northwest strike and steep dip, usually northeast, rendered schistose, wide distribution.	West coast Baranof and Chichagof islands, Douglas Island, Cleveland Peninsula, Gravina Island.
		(?)		
	4,000±	Slates; amphibole, chlorite, and mica schists interstratified with fossil-bearing limestone beds.	Closely folded, with general northwest strike, highly metamorphosed, very widely distributed.	Taku Harbor and George Inlet, fossil localities.
		(?)		
	600+	Light-colored limestones, with fossils	Broadly folded, northwest strike, metamorphosed.	Saginaw Bay, Keku Islets.
		Conformity.		
	200+	Sandstones, conglomerates, and argillites, containing igneous material, with fossils.		Soda Springs Bay.
		(?)		
Mississippian (lower Carboniferous).	1,500±	Gray limestone with cherty nodules	Highly tilted and broadly folded, northwest strike, widely distributed.	Iyoukeen Peninsula, Freshwater Bay, Gravina Island?.
		(?)		
Upper to middle Devonian.	800+	Melaphyre lavas, tuffs, with fossils	Broadly folded in northwest and northeast direction, metamorphosed.	Freshwater Bay, Frederick Sound, Pleasant Island.
		Conformity		
	1,500±	Limestone, with fossils		6 miles south of Klawak, San Juan Bautista Island.
		Conformity.		
	400+	Slaty limestone, argillite schists, with fossils		Clover Bay, Gravina Island.
		(?)		
Middle to lower Devonian.	1,800±	Gray limestone, with fossils	Broadly folded, with general northwest strike, highly metamorphosed in many places.	Frederick Sound, Flynn Cove, Davidson Inlet, Heceta Island, Long Island, Kasaan Peninsula, Glacier Bay.
		Conformity.		
	3,000±	Tuffs, sandstones, and conglomerates, composed of quartzite, chert, and limestone pebbles in tuffaceous matrix; no fossils.		
		(?)		
Silurian	2,000+	Gray to buff-colored limestone, semicrystalline, with fossils	Broadly and intricately folded and metamorphosed.	Glacier Bay, Meade Point, Kuiu Island, Flynn Cove.
		Probable conformity.		
	10,000±	Quartzites, graywackes, cherts; banded and indurated beds; no fossils	Closely and broadly folded in northwest and northeast directions, indurated and highly metamorphosed.	North end of Chichagof Island, Glacier Bay, west shore of Kuiu Island.

Many of the rocks grouped under the periods indicated in the stratigraphic column are synchronous with the formations represented along the Alaskan coast farther west and with those along the mainland and islands of British Columbia to the south. Correlation based on paleontologic evidence may also be made with the fossil-bearing strata in the States of Washington, Oregon, and California and with the formations in other parts of Alaska and in Canada. These comparisons, however, have been reserved for a future report.

ROCK FORMATIONS.

Along this portion of the Alaskan coast the distribution of the rock formations is known in only a general way. The geologic observations have necessarily been confined to the rock exposures along the coast of the mainland and islands, and the inland portions of many of the larger islands remain unexplored. The peculiar alignment along the mainland of the formations which are parallel to the Coast Range intrusives, and the many inland waterways which cut across these formations have greatly aided the general geologic reconnaissance of this region.

The dominant feature of the mainland, both structurally and petrographically, is the immense batholithic core of granite and diorite which occupies the central portion of the Coast Range throughout its length. The occurrence of this rock to the south in British Columbia, where conditions similar to those that prevail along the Alaskan coast are presented, has been discussed in detail by George M. Dawson. Brooks, in his report on the Ketchikan mining district, also gives it careful consideration, and Spencer in his report on the Juneau gold belt describes the occurrence of this intrusive rock and its relations to the intruded strata and to the ore deposits.[a] From Portland Canal north to Lynn Canal its western contact parallels the main coastwise channels. Just north of Berners Bay it crosses Lynn Canal, and its western contact extends north along the east side of Chilkat Valley.

Bordering this intrusive core of the Coast Range is a band of closely folded crystalline schists composed largely of Carboniferous strata and in places having a width of several miles. In this province these rocks were termed the Ketchikan series by Brooks,[b] and in the Juneau district the corresponding rocks are grouped together as the "Schist band" by Spencer.[c] These crystalline schists have been traced from the southern boundary of Alaska to the head of the Chilkat basin at the British Columbia boundary. The strata are essen-

[a] The Coast Range intrusives and their bearings on the ore deposition are considered at length on pp. 61–69 of this report.

[b] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902.

[c] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906.

tially siliceous mica schists, feldspathic schists with intercalated amphibole and chlorite schists, and occasional beds of crystalline limestone containing Carboniferous fossils. Narrow outlying belts of the Coast Range intrusives invade these schists, and near the contacts with these as well as with the main mass the schists are cut by a network of pegmatite dikes and quartz veinlets. In places the alteration of the beds has been so intense as to produce gneiss, which near the intrusive contact has been thoroughly recrystallized and rendered massive, so that it is not everywhere possible to distinguish with certainty the line of contact between the intrusive and bedded rocks.

To the southwest the beds become less schistose, and "black slates," intruded by altered dikes of andesitic and gabroic rocks, predominate. The latter are more prominent along the mainland in the Juneau district than to the south. Intercalated beds of altered lavas and tuffs, usually called greenstones, gradually find place in the slate belt, and farther southwest great thicknesses of these greenstones occur. Such a belt of massive greenstone beds is well exposed at the following places: The shores of Tongass Narrows at Ketchikan, the west end of Cleveland Peninsula, Woewodski Island in Duncan Canal, Cape Fanshaw, Glass Peninsula, and the west side of Douglas Island.

Beyond this belt toward the outer coast the geologic section and bed-rock structure across southeastern Alaska change with the latitude, and beds of one formation can not be traced for any great distance northwesterly as can the rocks along the mainland. This is largely due to the irregular batholithic intrusives which occupy the central portions of most of the islands and are similar in composition to the Coast Range granite. Since detailed descriptions of the areal geology and sections across the Ketchikan and Wrangell districts follow, it is necessary to add here, for the purpose of comparison, only a short discussion of the rock occurrences on the northernmost islands of the archipelago.

On Admiralty Island the underlying stratified rocks are broadly folded limestones and schists, mainly of early Carboniferous age. At both Pybus Bay and Herring Bay collections of upper Carboniferous fossils were made. At the entrance to Pybus Bay lower Cretaceous fossils were gathered from calcareous shales which overlie the Carboniferous beds uncomformably. The basin of Kootznahoo Inlet is occupied by a considerable thickness of sandstones and conglomerate beds containing coal seams with fossil plants of Eocene age. The basalt lava flows which cover the southern end of the island southeast of Pybus Bay represent the most recently formed rocks. Invading all of the stratified rocks of Paleozoic age are irregular granite masses occupying small areas.

The geology of the two seaward islands, Baranof and Chichagof, also presents many interesting features. The central portions of the islands are made up of granitic intrusives forming broad belts that strike across the islands in a northwesterly direction and invade all the bedded rocks except the recent lavas. The mineral deposits are located near the contacts with these granite masses. The oldest rocks are strata of banded quartzite resembling graywacke and chert in places. These beds are exposed for several miles along the north shore of Chichagof Island between Idaho Inlet and Frederick Sound, where they form a large anticline striking northwest. To the west they are invaded by a wide belt of granite, which has altered them to a compact biotite schist. Along the northeast shore from Frederick Sound to Point Augusta they again form the shore outcrops. Though the thickness of this formation could not be determined, it probably represents many thousands of feet of sedimentation. Overlying the quartzites are cherty limestones in which middle Devonian fossils were found in Frederick Sound and on the south side of Freshwater Bay.

The upper Devonian formation is represented by melaphyre lava flows and tufaceous beds; fossils were collected from the latter along the west shore of Frederick Sound. These beds extend southeasterly into Freshwater Bay. Limestone of considerable thickness overlies the melaphyres and is exposed in Frederick Sound and along the northeast shore of Freshwater Bay. At these places large collections of lower Carboniferous fossils were obtained. West of the granitic core on the seaward shores of both Chichagof and Baranof islands is a series of crystalline schists and limestones, overlain by a belt of slates and greenstones of upper Carboniferous age. The latter in turn are overlain unconformably by a wide belt of considerably metamorphosed graywackes and conglomerates, which are prominent in the vicinity of Sitka and Point Edward. A remarkable analogy exists between this section and the cross section of the mainland belt in the vicinity of Juneau. The most recent rock formations on the seaward islands are the postglacial basaltic lava flows on Kruzof Island.

STRUCTURE.

The structural characteristics of the stratified rocks of the different geologic horizons in southeastern Alaska are noted in the table on page 34 and in the geologic section accompanying each geologic map. However, a formation may be intricately folded and highly metamorphosed at one locality, but at another it may be characterized by broad folds and a much less amount of metamorphism, so that in such a table it is possible to present only the more typical structural features. A brief consideration of these structural phenomena and their relations to the geologic history is therefore necessary.

By a consideration of the entire coastal province of southeastern Alaska, several important features which throw light on the dynamic history of the region are brought out. In the Ketchikan and Wrangell districts alone these features are not so clearly marked. Prior to the development of the main northwest-trending structural lines, which at present dominate this coastal province and are most pronounced adjacent to the wide areas of intrusive rocks, the prevalent structure was made up of northeasterly trending folds. These folds still form a minor system prominent on Chichagof, Admiralty, and Prince of Wales Island. The later and more intense folding of the beds on a broader scale, which forms the major system and trends northwesterly, has in general obliterated this minor system. But the evidence of the two systems is clearly presented on the north shore of Chichagof Island, where the minor system of small folds is the dominant structure at those places which are distant from the northwest-trending intrusive belts and which are not greatly disturbed and metamorphosed. Nearer the intrusive belts the larger system gradually prevails, and the minor folds as a whole are combined in the broader anticlines and synclines of the major northwest-trending folds. Complex minor folding and fracturing is thus produced in the beds. The fact that beds of upper Carboniferous age have this northeasterly folding indicates that this was the dominant bed-rock structure at the close of the Paleozoic era. Whether the younger system of folding was produced just previous to the intrusion of the Coast Range granite, or at the time of its invasion, has not been definitely established, though, as suggested by Spencer,[a] it was probably before the invasion of these igneous rocks, as the planes of contact, with few exceptions, follow the planes of bedding, and to present this structure the strata must have been highly tilted and must have occupied a position similar to that which they now have. Along the mainland, across a width of from 5 to 10 miles, the uniformity of the strike and dip of the stratified rocks adjacent to the Coast Range granite indicates a monoclinal structure. Such interpretation, however, would necessitate a still greater thickness of the rock beds at the time of their deposition, as in their present condition they are greatly compressed and metamorphosed. From the evidence of broad folding of the beds, believed to be the same, which are exposed along the west shore of Admiralty Island, it is reasonable to assume that this rock belt has the structure of a closely folded and compressed synclinorium, and that the tops of the anticlines were subsequently removed, leaving little or no definite proof of their existence.

After this great period of mountain building, which is believed to have occurred about the close of Paleozoic or in early Mesozoic time, further important orogenic movements of the earth's crust took place

[a] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906, p. 14.

and are clearly shown in the Mesozoic beds on Admiralty and Prince of Wales islands. The *Aucella* beds on Admiralty Island are steeply tilted and faulted and to some extent metamorphosed, but they do not show close folding or uniformity in direction of strike. On Prince of Wales Island beds, probably of Mesozoic age, though nonfossiliferous, overlie the granite intrusives; at certain localities they have assumed a steeply tilted position with northwesterly strike and are considerably metamorphosed, while at other places they are only slightly folded and show no persistent direction of strike or dip and but little metamorphism. The forces producing this later structure affected the older Paleozoic strata largely by faulting, fissuring, and tilting, and not by intense folding. The structural characteristics in the Tertiary (Eocene) beds and those of late Cretaceous age indicate tilting and faulting and there is little or no evidence of folding or metamorphic action. The effects appear to be confined largely to the basins or local areas occupied by these rocks, and in the older beds faults and fissures were probably produced along which the basaltic lavas subsequently found egress.

In addition to the preceding description of the different periods of dynamic revolution, the structurally significant faulting which accompanied these orogenic movements deserves special consideration. Evidence of these faults, however, is shown largely by the local discontinuity of the strata, as surface indications have been removed by erosion. Moreover, those faults, possibly numerous, which are parallel to the bedding, are difficult to decipher, because of the extreme metamorphism of most of the rocks. Only the structurally important faults which show large displacement and the minor faults or slipping planes in the ore bodies and in shore exposures were noted.

The largest and most important fault plane in southeastern Alaska, which is suggested both geologically and topographically, extends from the head of Lynn Canal in a S. 10° E. direction 200 miles or more through Chatham Strait into the Pacific Ocean. The displacement at its southern end is evidently greater than at the head of Lynn Canal, where the main fault appears to diverge into two or more directions indicated by Taiya Inlet, Ferebee River, and possibly Chilkoot Inlet and River. The displacement and the direction of throw of this fault are not clearly defined, though the former probably amounts to many miles.

Detailed work in this province will doubtless reveal many other faults that are structurally important. Minor faults and slipping planes noted in the ore bodies, stratigraphically of little significance, though economically of great importance, are discussed in the detailed descriptions of the ore bodies.

MINERAL DEPOSITS.

Metallic mineralization in southeastern Alaska is confined to certain rock formations, and in these the mineral deposits occur to some extent along certain zones which have been more or less satisfactorily determined. Because of the rough topography and the dense growth of forest and underbrush, investigations of such belts have necessarily been limited to the vicinity of salt water, where the rock formations and mineral belts are clearly exposed.

The direct relation of mineralization, or the occurrence of ore, to the rock structure and to the intrusive rocks is at many places very evident. Most of the ore bodies are found near or, more rarely, in the larger intrusive masses, and especially in those places where the general rock structure trends northwesterly. In a broad way, the mineral deposits are coextensive with the areas of granitic intrusives and occur in the adjacent metamorphic rocks affected by such intrusives.

The most extensive and productive area is the Juneau gold belt,[a] which has been irregularly traced along the mainland from Windham Bay to a point 10 miles north of Berners Bay, where it enters Lynn Canal. Its total length is 120 miles and its width less than 10 miles. In this zone gold is the dominant metal present and occurs in varying amounts disseminated with sulphide minerals in bands of schistose rock 10 to 60 feet wide, in altered diorite dikes, where it is associated with stringers of quartz, and in quartz veins, 1 to 10 feet wide, cutting either the intrusive or schistose country rock. The ore bodies within this zone are discussed at length by A. C. Spencer in his report on the Juneau gold belt.

In the Wrangell district the concentration of metallic minerals along definite zones has apparently not taken place, though a number of mineral prospects have been found, namely, in Thomas and Le Conte bays, along Bradfield Canal, and in Groundhog and Glacier basins. At the last two localities silver and lead ores, occurring in quartz veins inclosed in the crystalline schists, are prominent, while at the others gold is the dominant metal present. Within the mainland belt of the Ketchikan district, which includes Revillagigedo Island, quartz veins and mineralized schist bands are found locally, but they are too widely separated to permit the definition of a mineral zone like that in the Juneau district. The slates and greenstones contain the largest percentage of metallic minerals, and in them deposits have been developed on Gravina Island, along the west shore of Revillagigedo Island, and on Cleveland Peninsula. In the slates and schists nearer the Coast Range intrusives, vein deposits have been found at the head of Thorne Arm and in George Inlet.

[a] Bull. U. S. Geol. Survey No. 287, 1906.

On the larger islands of southeastern Alaska the regularity of the rock structure and the continuity of the formations is locally interrupted by intrusive areas of granitic rocks and wide channels separating the islands. For this reason it is not possible to trace for any great distance mineral zones comparable with those along the mainland. The occurrence of the deposits on each island differs somewhat, and the islands are described separately in this paper. In general, the ore bodies appear to be closely connected with the intrusive rock masses, many of them lying at or near the contacts of the intrusives.

On Admiralty Island the areas of intrusive rocks, so far as known, are small, and the occurrence of valuable mineral deposits relatively rare. A poorly defined mineral zone starts at a point just north of Windfall Harbor on the west side of Seymour Canal and is traceable northwestward to Funter Bay. It is about 30 miles long and 2 miles wide and includes several prospects but no producing mines. Other prospects are located on the west coast of the island a few miles north of Kootznahoo Inlet.

On the two seaward islands, Baranof and Chichagof, which constitute the Sitka mining district, a poorly defined mineral zone occurs in the metamorphic schists flanking the west side of the intrusive belt, starting at Red Bluff Bay, on the east side of Baranof Island, and extending northwestward, including the prospects at the head of Silver Bay and in the vicinity of Cape Edward, north of which it enters the ocean. Auriferous vein deposits are the principal type of ore body in this mineral zone. Another zone of mineral-bearing schists was noted along the eastern side of this intrusive belt extending from Hooniah Sound to Lisianski Straits and northwestward on the mainland from Cape Spencer to Lituya Bay, where it flanks the St. Elias Range. Only a few prospects in the vicinity of Rodman Bay and at the head of Hooniah Sound have thus far been located in this mineral zone.

On Kupreanof Island scattered indications of a widespread mineral-bearing zone extend from the head of Portage Bay down the east side of Duncan Canal and include prospects along the west shore of Wrangell Narrows. The ore bodies thus far opened carry small values in both copper and gold. No deposits of ore have yet been discovered on Kuiu Island.

The distribution of mineral deposits on Prince of Wales Island, like that on the other islands, is dependent upon the intrusive areas. Here the direct relations of the ore bodies to the intrusive rocks are more evident because they occur in many places along the contacts of the intrusive and intruded rocks. Copper is the dominant metal in many of the deposits. It is present within the contact aureoles of the intrusive masses, as on Kasaan Peninsula and in the vicinity of

Hetta Inlet, and occurs as lenticular masses or veins along shear zones in a greenstone schist country rock, as at Niblack and Copper City. Gold accompanies the copper deposits as an accessory constituent and is found in vein deposits inclosed in limestones at Dolomi and in black slates or phyllites in the vicinity of Hollis.

GEOLOGY OF THE KETCHIKAN AND WRANGELL MINING DISTRICTS.

GEOLOGIC MAPS.

Three geologic maps accompany this report (Pls. I, II, and III, in pocket); the first is a general geologic map on a scale of 10 miles to 1 inch and includes both the Ketchikan and Wrangell mining districts; the other two are of larger scale and show in greater detail the geology along the mainland portion of each district and the topography of this portion so far as it has been mapped. The general geologic map has been introduced to show the distribution of the two large rock types, the sedimentary and the igneous.

The sedimentary rocks, which are important to the geologist in deciphering the geologic history of a region, are subdivided into three groups separated by their differences in age. The oldest group—the Paleozoic strata—embraces a number of unconformable series which are much folded and in places highly metamorphosed. They are known to range in age from Silurian to upper Carboniferous and to have their most extensive development during the Carboniferous. A number of different formations belonging to this era have been recognized and distinguished one from the other at various localities, but, as their continuity and their lines of separation are only partially known, a differentiation of them has not been made on the map. The localities at which fossil evidence has been found are shown on the map by letters indicating the stratigraphic horizon represented. In the following pages these fossil localities are described and the known stratigraphic succession of the Paleozoic rocks is discussed.

The sediments of the Mesozoic era are represented only locally by interstratified slate, graywacke, and conglomerate beds of considerable thickness. These strata are often metamorphosed, indurated, and considerably folded, and in most places contain no fossils. Their classification is therefore based largely on structural and petrographic evidence. These rocks have been mapped as a unit but are considered at length in the following descriptions.

The Tertiary sediments are made up of shale, sandstone, and conglomerate occupying small areas which in places are coal-bearing. The unmetamorphosed and loosely consolidated state of these beds, the presence in them of numerous fossil plants, and the lack of in-

tense folding are their principal characteristics. Paleontologic evidence shows these beds to be essentially of Eocene age, but at one point fossil plants of late Cretaceous age were identified.

The igneous rocks represented on the map fall into two classes, the intrusives and the extrusives, the latter being subdivided according to their composition and the period of extrusion. The areas of the intrusive rocks of this province are especially noteworthy because of their direct bearing on the occurrence of ore deposits. Their relations and the characteristics of the extrusive rocks are discussed in the following pages.

The two maps of larger scale, showing the eastern portions of the Ketchikan and Wrangell districts, have been introduced to show in greater detail the geology of the mainland belt and the topographic relief. These two maps and the map of the adjoining Juneau gold belt [a] to the north form a continuous geologic and topographic sheet from Portland Canal to the head of Lynn Canal. All the sedimentary rocks indicated on the Juneau map are of Paleozoic age and occur in broad bands that have a general northwesterly trend and are traceable for nearly the entire length of the mainland belt.

Adjacent to the Coast Range intrusives and in places occupying small narrow areas within the intrusive belt is a succession of crystalline schists and limestone from 5 to 15 miles in width, composed largely of Carboniferous rocks. These in the Ketchikan district have been described as the "Ketchikan series," by Brooks,[b] who also refers them to the Carboniferous. Spencer [c] describes those to the northwest in the Juneau district as the "Schist band." To the southwest, across the trend, these rocks become less crystalline and this is indicated on the geologic map by the fewer dashes. Still farther southwestward black slate and argillites gradually dominate, and to the northwest they have been mapped as the "Slate belt" by Spencer. These slates bordering the coastwise channels are interstratified with volcanic tuffs and lava flows, which in turn dominate in amount over the sedimentary material and form the band mapped as greenstones. In the Juneau district the same succession of igneous and sedimentary rocks is present, and is described by Spencer as the "Slate-greenstone band." On the adjacent islands the areas mapped as "Undifferentiated Paleozoics" include slates, schists, limestones, and some conglomerates, which are either Carboniferous or Devonian in age. The fossil localities are indicated, as on the smaller scale map, by letters representing their stratigraphic horizon. The strata of crystalline limestone, mainly Carboniferous, which are important both stratigraphically and economically have been indicated sepa-

[a] Bull. U. S. Geol. Survey No. 287, 1906, Pl. XXXVII.

[b] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902, p. 42.

[c] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906, p. 16.

rately. The directions of both strike and dip of the structurally important rock beds are indicated, and the positions of the mines and prospects are shown.

Geologic sections transverse to the general direction of strike have been made for each of the three maps, and in them the known structural features are represented and are supplemented by more or less hypothetical dotted lines. The geologic maps and cross sections will be referred to in the following geologic descriptions, and the descriptions should be considered together with the maps.

SEDIMENTARY ROCKS.

GENERAL STATEMENT.

The general sequence of geologic formations in southeastern Alaska as a whole is presented in tabular form on pages 34, 35. This table applies to the Ketchikan and Wrangell districts, though in these districts all the formations noted have not been recognized. The distribution of the large subdivisions is shown on the geologic maps, and their relations are indicated to some extent in the geologic cross sections. Though the present geologic data of this province do not give a complete record of the different periods of rock deposition, the general succession has been fairly well established by structural and paleontologic evidence, and is discussed in the following pages in some detail.

Of the earliest rock formations little or nothing is known, and it is doubtful whether pre-Paleozoic strata are present in this province. The crystalline schists and gneissoid rocks, which form a wide band adjacent to the Coast Range and resemble the ancient metamorphic clastics of other regions, have been determined by paleontologic evidence[a] to be mostly of late Paleozoic age, and their present crystalline condition is attributed to metamorphism caused by the Coast Range intrusives.

PALEOZOIC STRATA.

SILURIAN.

The sedimentary record begins with the Silurian, which is represented by fossiliferous limestone strata. These overlie with apparent conformity a banded quartzite of great thickness, and the limestone and quartzite together form a belt, exposed at irregular intervals on the west coast of Prince of Wales and Kuiu islands, which extends northward and is again represented on Chichagof Island in Glacier Bay. Under the name "Wales series" Brooks[b] included these older rock terranes. The banded quartzites are usually extremely fine

[a] See paleontologic determinations, p. 39.
[b] Op. cit., p. 41.

grained or aphanitic, indurated, clastic rocks, gray to green in color, very brittle, and with no cleavage. They include both sedimentary strata and indurated beds of tuff intermixed with sedimentary material. Weathering usually produces a brown surface by the oxidation of pyrite and other ferruginous particles.

The Silurian limestones are best developed on the north side of Kuiu Island between Saginaw and Security bays. From the south side of Saginaw Bay a wide belt of cherty nonfossiliferous limestone strikes parallel to the shore with a northeasterly to vertical dip. This formation continues to a point one-half mile west of the entrance to the bay. At this point in the lower portion of the limestone belt fossiliferous beds were found by E. M. Kindle, who reports as follows:

Fauna of the Meade Point limestone.—Fossils were found at but one locality in this limestone. They occur just east of the third cove northeast of Meade Point on the third point west of Saginaw Bay. The fauna contains a small number of species, but one of these, *Conchidium knighti*, is represented by very many shells in one thin bed of limestone. The fauna includes the following forms:

Diphyphyllum ? sp.
Conchidium knighti (Sow.).
Whitfieldella sp.
Holopea cf. servus Barr.
Murchisonio sp.

Conchidium knighti is one of the most characteristic fossils of the Aymestry limestone of the Ludlow group of England. It is known also from Russia and Bohemia. There appear to be no authentic records of its occurrence in the Silurian faunas of the United States. The fauna indicates a horizon of the upper part of the Silurian, but somewhat earlier than the Silurian fauna at Freshwater Bay or Chichagof Island.

Southwest of these fossiliferous limestones, on the opposite side of a small cove, banded quartzite beds underlie the limestones with apparent conformity and continue southwest with northwesterly strike and northeasterly dip, forming the bed rock of Security Bay. From Security Bay southward the quartzites are exposed along the entire western shore of Kuiu Island, a distance of nearly 50 miles, and are interrupted only locally at Washington Harbor and at the head of Pillar Bay by granitic intrusions. Along this entire coast no observations indicated that there was a duplication of these beds, but it is probable that duplication exists. The total thickness of the beds cannot, therefore, be estimated, though it must amount to many thousands of feet.

DEVONIAN.

At the base of the Devonian are conglomerates of considerable thickness, which contain pebbles and cobbles derived from the older Silurian beds. This fact suggests an unconformity between the Silurian and Devonian strata, though neither in the Ketchikan nor in the Wrangell districts were these two formations observed in contact with each other.

Along the northwest shore of Prince of Wales Island and on the smaller islands adjacent to Davidson Inlet limestone of considerable thickness at many points overlies these conglomerate beds, and together they represent the lowest horizon of the Devonian. These conglomerates consist essentially of cobbles of banded quartzite with some limestone and schist fragments. Toward the limestone beds they grade into sandstone and slaty limestone. They are conformably overlain by the limestone strata. Narrow beds of the sandstone also occur interstratified with the limestone beds. The limestones are semicrystalline and gray to blue in color, and not many of the fossil remains in them are preserved. At several points, however, imperfect fossil remains were gathered; the largest collection was obtained on the east shore of Heceta Island from beds directly overlying the conglomerates. Kindle reports as follows on this collection:

Cliff on east side of Heceta Island.—The fauna from this locality includes *Stropheodonta* cf. *comitans* Barr., *Gypidula* cf. *opatus*, *Atrypa reticularis*, *Pentamerus* cf. *procerulus*, *Atrypa* cf. *aspera*, and several undetermined species.

The horizon is apparently lower Devonian. A fragmentary shell which seems to represent a finely plicated *Conchidium* indicates a horizon not later than early Devonian.

The total thickness of the conglomerate beds is estimated at 1,200 feet and that of the overlying limestone strata at 1,800 feet. At this locality the rock beds are broadly folded and considerably metamorphosed.

A somewhat higher horizon of the Devonian is represented by the fauna contained in the limestone beds on Long Island, in Kasaan Bay, on the east side of Prince of Wales Island. At this locality both lower and middle Devonian fauna have been recognized, though the limestone strata containing them are apparently conformable. The first fossils from this locality were gathered by Brooks[a] in 1901, and were determined as middle Devonian by Prof. Charles Schuchert. In 1905, E. M. Kindle made a more complete collection at this locality and submits the following report:

Blue limestones form much of the surface outcrops on a group of small, low islands near the middle of Kasaan Bay, of which Long Island is the largest. On Round Island the limestones are not greatly metamorphosed, but have occupied a zone of vigorous deformational activity. The island affords an uninterrupted outcrop of the limestones entirely around its shore line. These outcrops are of particular interest as illustrating in a small area the complex character of the deformation in this region. The beds are everywhere inclined at a high angle, usually about 90°. On the north and east sides of the island the strike is within a few degrees of due north. From nearly due north the strike swings around abruptly to N. 80° E. on the west side of the island. The exposures on the west side show the sharp elbow which the nearly vertical strata make in

[a] Op. cit., p. 43.

changing from a northerly to an easterly strike. The limestone on Round Island is shown by its fossils to be of the same age as the upper beds on Long Island, which lie a few hundred yards southeast.

On Long Island, which has a length of about 2 miles and an average width of less than one-half mile, the limestones show a less degree of deformation than those of Round Island. The flexures have comparatively gentle dips, amounting in parts of the southeastern portion of the island to only 5° or 10°. In the western part of the island, however, the dip rises to 90°. The strike, as on Round Island, varies greatly.

A section along the south side of Long Island from the east end to Salt Pond shows the following series of beds:

Section 12, Long Island.

	Feet.
c. Hard, dark-gray limestone, slightly darker than the preceding	270
b. Hard, blue, fine-grained limestone, fracturing easily in any direction	200
a. Buff or cream-colored feldspathic sandstone underlying the limestones	90
	560

The two divisions of the limestone series are conformable, and the upper and lower portions are very similar in lithologic character. Analyses of the upper and lower portions of the limestone series show them to be very similar in chemical composition, one carrying 96.11 per cent, the other 97.50 per cent of lime.

Aside from the faunal differences, which are quite marked, there are no very evident reasons for making two divisions of the limestones.

Fauna.—The character of the fauna in the lower section (*b*) of the limestone series is indicated by the following list:

Strictopora sp.
Cladopora sp.
Spirifer cf. sulcatus, Hisinger.
Sanguinolites sp.
Cardiola sp.
Hercynella nobilis, Barr.
Hercynella behemica, Barr.
Holopea sp.
Murchisonia angulata Phillips.
Murchisonia sp. 1.
Murchisonia sp. 2.
Planitrochus cf. amicus.
Loxonema sp.
Holopella sp.
Trochonema sp.
Euomphalopteris ? sp.
Operculum.
Beyrichia ? sp.
Leperditia sp.
Orthoceras sp.

The occurrence of the genus Hercynella in this fauna is of considerable interest, since it has not been found heretofore in America. *H. bohemica* occurs in the lower Devonian of the Ural mountains. Both *H. bohemica* and *H. nobilis* are present in étage F of Barrand's Bohemian section. Their presence in the fauna at Long Island indicates that the latter is much more closely related to the European and Asiatic than to the American faunas outside of Alaska. This lower fauna at Long Island represents the lowest Devonian horizon which has been found in Alaska.

In the upper portion of the higher limestone (*c*) the following fauna are found:

Favosites cf. radiciformis Rom.
Cyathophyllum sp.
Orthophyllum ? sp.
Zaphrentis sp.
Calceola cf. sandalina.
Syringopora sp.
Lingula cf. bohemica.
Atrypa reticularis Linn.

Atrypa hystrix Hall.
Gypidula opatus (Barr).
Gypidula cf. interveuicus (Barr).
Meristella cf. barrisi Barr.
Stropheodonta stephani (Barr).
Spirifer sp.
Spirifer hians Bich. ?
Spirifer thetidis Barr.
Spirifer Subcomprimatus Tsch.
Spirifer sp.
Spirifer indeferens Barr.
Spirifer sp.
Reticularia ? sp.
Rhynchonella cf. amalthea Barr.
Rhynchonella livonica Buch.
Pugnax sp.
Dalmanella occlusa Barr.
Schizophora macfarlani Meek. ?
Schizophora striatula Schloth.
Streptorhynchus sp.
Stropheodonta comitans Barr.
Camarotoechia ? sp.
Cypricardinia ? sp.
Concardium cf. behemicum Barr.
Concardium sp.
Lucinia cf. proavia Goldf.
Leptodesma sp.
Mytilarca sp.
Nuculites sp.
Tellinopsis sp.
Holopella ? sp.
Loxonema ? sp.
Murchisonia sp. 2.
Murchisonia sp. 1.
Naticopsis sp.
Oriostoma sp.
Oriostoma princeps var. Oehlert.
Euomphalus cf. planorbis D'Arch and Vern.
Tremanotus cf. fortis Barr.
Tentaculites sp.
Ooceras sp.
Gomphoceras ? sp.
Orthoceras sp.
Cytherella ? sp.
Entomis pelagica Barr.
Lepterditia sp.
Cyphaspis sp.
Proetus sp.
Proetus cf. romanooski Tsch.

In place of the gasteropods which are the dominant forms in the lower horizon the brachiopods are the predominant group of this fauna. The Hercynellas, which are abundant at five horizons in the lower beds, appear to be entirely absent. The upper fauna, however, agrees with the lower in its foreign affiliations. In it occurs the peculiar coral, *Calceola*, very common in the middle Devonian of Europe. Several specimens among the brachiopods are either identical with or have their nearest analogy in European species. The fauna represents a middle Devonian or late lower Devonian horizon.

The lowest 40 feet of division *c* of the Long Island section furnished a fauna differing but slightly from that of the upper part. The following list indicates its character:

Cladopora?
Cyathophyllum sp.
Camarotœchia sp.
Meristella cf. Ceres Barr.
Spirifer sp.
Spirifer cf. thetidis Barr.
Spirifer cf. cheiropteryx.
Stropheodonta comitans Barr.
Orthonota sp.
Schizodus sp.
Conocardium cf. behemicum Barr.
Euomphalus planorbis d'Arch and Vern.
Oriostoma princeps var. Oehlert.
Tentaculites.
Cyrtoceras sp.
Orthoceras sp.
Proetus cf. romanooski Tsch.

The stratigraphic relations of Long Island limestones to the geological horizons represented on the adjacent shore of Kasaan Bay can not be definitely determined because of their topographic isolation.

The middle Devonian horizon again occurs about 20 miles south of Long Island, at the head of Clover Bay, where a small area of schistose argillites and black limestone is found almost completely

surrounded by an intrusive diorite mass. These beds are highly tilted and have a general east-west strike. Fossils gathered from this locality were determined by E. M. Kindle, as follows:

No. 421.—Southwest side of Clover Bay, east coast of Prince of Wales Island. The fossils, which are badly distorted, include the following species:

Favosites cf. hemisphericus.	Camarotœchia cf. billingsi.
Schizophoria cf. striatula.	Pentamerella ? sp.
Stropheodonta perplana.	Atrypa reticularis.
Chonetes cf. mucronatus.	Schizodus sp.

The age is Devonian. The faunal evidence, though not conclusive, suggests that the horizon is probably middle Devonian.

This occurrence shows that argillites as well as limestones were deposited during middle Devonian time, but no stratigraphic relations could be determined because they are surrounded by the intrusive mass.

At Vallenar Bay, on the north end of Gravina Island, beds of shaly limestone, argillaceous schist, and schistose conglomerate containing middle Devonian fauna occupy the structural crest of an anticline. These beds underlie the slates and greenstones which border both the east and west shore of the island. Fossils were first found at this locality by Brooks in 1901, and were determined by Charles Schuchert to be Devonian. In 1905 a collection was made at this locality by E. M. Kindle, and in 1906 more material was gathered by the writers. Kindle reports as follows:

One mile west of Vallenar Bay, Gravina Island.—The material from this locality, while generally insufficient for specific determination, is much better than that obtained last year (1905) and leaves no doubt as to the Devonian age of the beds west of Vallenar Bay. Several specimens of *Atrypa reticularis* are present. This species fixes the horizon as not later than Carboniferous, while the association of *Chonetes* cf. *manitobensis*, *Spirifer* sp., *Proetus* sp., and *Cyclonema* sp. indicate a horizon of Devonian age, probably middle Devonian.

The Devonian beds at this locality and those on Long Island are included under the name "Vallenar series" by Brooks[a] and are described in his report on the Ketchikan district.

Limestone beds containing an upper Devonian fauna, and overlying with apparent conformity banded argillaceous beds similar to those of middle Devonian age exposed at Clover Bay, occur in a small cove 6 miles south of Klawak on the west coast of Prince of Wales Island.

Kindle reports as follows on a collection made at the above locality:

No. 854.—Point 6 miles south of Klawak, west coast of Prince of Wales Island.

[a] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902, p. 42.

Fauna comprises:

Zaphrentis sp.
Cyathophyllum cf. geniculum.
Cladopora cf. rœmeri.
Productella hallana.
Spirifer cf. anossofi Verneuil.

The *Productella hallana* and *Spirifer* cf. *anossofi* Vern., are represented by a number of specimens and seem to be the most abundant fossils at the locality. *S. anossofi* is a representative of the Ural Mountain fauna, and is closely related to *S. hungerfordi* of the Iowa Devonian. *Productella hallana* is a common species in the western American Devonian and is also found in the Ural Mountains. The horizon represented by this fauna is upper Devonian.

Three miles northwest of the above locality, on a point opposite Fish Egg Island in Klawak Inlet, the same horizon is again represented. The limestone beds strike northerly with steep dip to the northeast, and are underlain as at the above locality by banded siliceous slates. The duplication at these localities is apparently due to folding, though the folds were not clearly defined.

Kindle makes the following report upon the fossils collected at this locality:

Point north of Fish Egg Island, Klawak Inlet, near Prince of Wales Island.—A small collection from this locality is composed mainly of corals and small ostracods. It includes *Stromatopora* sp., *Cyathophyllum* sp., *Striatopora* sp., and *Cyrtina* n. sp. This assemblage indicates a horizon of probably late Devonian age. The *Cyrtina*, with finely striated fold and sinus, suggests a horizon not earlier than upper Devonian.

South of these two localities of upper Devonian fauna, on the east side of San Juan Bautista Island, the same horizon is again represented. The limestone beds at this point strike northwesterly with a flat dip to the southwest, and a wide belt of granite invades them and occupies the central part of the island (Pl. I).

Kindle submits the following report on the fossils gathered at this point:

Southwest end of San Juan Bautista Island.—The presence of *Spirifer disjunctus* and *Productella* cf. *lachrymosa* in the fauna from this locality indicates a horizon of upper Devonian age. There are also present *Cyathophyllum* sp., *Athyris* cf. *angelica*, *Atrypa reticularis*, and other species.

The limestones at the latter localities represent the uppermost horizon of the Devonian recognized in this province. To the north, however, on Chichagof Island the upper Devonian is terminated by a considerable thickness of submarine melaphyre lava flows and tuffs interstratified with and overlying upper Devonian limestone beds. Fossils were also present in the tuff beds, thus defining the age of these extrusives. These melaphyre lavas, however, were not observed in the Ketchikan or Wrangell districts.

The distinctions between the three divisions of the Devonian, the upper, middle, and lower, in most places are not clearly defined paleontologically, and at no locality was a complete section of these

horizons obtained. It was therefore, necessary to group the Devonian under two divisions in the stratigraphic table (p. 35), namely, upper to middle Devonian and middle to lower Devonian.

CARBONIFEROUS.

The stratigraphic relations between the early Carboniferous and the late Devonian formations are not definitely known, and in no place were the formations observed together. On Chichagof Island, north of this province, lower Carboniferous limestones overlie the upper Devonian volcanic beds with apparent conformity, though this relation was but poorly defined. The same horizon of the lower Carboniferous is represented by fossil-bearing limestones on an islet at the entrance to Soda Springs Bay, on the west coast of Prince of Wales Island. The limestone beds strike northerly and are steeply tilted toward the east; they overlie with apparent unconformity conglomerates and sandstones which resemble those of early Devonian age. On Prince of Wales Island opposite this islet are slates and chlorite schists which resemble those probably belonging to the upper Carboniferous.

The collection of fossils from this locality was referred to G. H. Girty, who reports the following:

The Soda Springs Bay collection contains the following forms:

Zaphrentis sp.
Menophyllum? sp.
Derbya sp.
Schizophoria? sp.
Chonetes sp.
Productus aff. punctatus.
Productus aff. mesialis Hall.
Productus aff. setiger Hall.
Productus hirsutiformis Walcott.
Productus aff. cora D'Orbigny.
Productus aff. concentricus Hall.
Productus aff. burlingtonensis Hall.
Spirifer aff. bisulcatus Sowerby.
Spirifer aff. keokuk Hall.
Spiriferina sp.
Reticularia aff. setigera Hall.
Athyris aff. lamellosa L'Eveille.

This lot clearly belongs to the lower Carboniferous fauna.

On the south end of Gravina Island 3 miles north of Dall Head fossils were found in beds of calcareous schist, which because of their ambiguity could not be definitely determined, but are provisionally referred to the lower Carboniferous. These, however, may represent a Triassic horizon.

Girty reports as follows on this collection:

Cove 3 miles north of Dall Head, west side of Gravina Island.

Zaphrentis sp.
Lithostrotion sp.
Cyrtina sp.
Martinia ? sp.
Dielasma ? aff. bovidens Tschern., non Martin.
Dielasma ? aff. millepunctatum.
Aviculipecten ? sp.
Halobia ? sp.
Pteria ? sp.
Tetinka ? cf. bellula Barrande.
Loxonema ? sp.
Euomphalus ? sp.
Pleurotomaria sp.
Naticopsis sp.
Several undetermined forms.

By the presence of *Halobia?*, which is very similar to if not identical with that which occurs in lot 17 on the Yukon (determined as lower Carboniferous), as well as by certain other particulars, a correlation of the two horizons is suggested, and perhaps for the present that is the best disposition which can be made of this very ambiguous collection. At the same time the two faunas are rather widely different.

Few data exist concerning the interval between the lower and upper Carboniferous faunas, as the two formations are nowhere present at the same locality and no fauna representing the intervening period has been found. The upper Carboniferous, which probably includes the most extensively developed formations, is represented by limestone beds at Saginaw Bay and Keku Islets at the north end of Kuiu Island. The beds there overlie sandstone and conglomerate with a suggestion of unconformity. The determination of the fossils contained in several collections from the limestone beds on Keku Islets and Saginaw Bay indicates a lower and an upper series, both of the upper Carboniferous formation. Girty in his report on these collections states:

These two series, but especially the upper, are what have previously been determined as Permian in the Alaska Range, but I really find that the resemblance with the Gschelian stage of the Russian section is greater than with the Russian Permian. Provisionally, therefore, I will correlate this horizon with the Gschel-stufe, in which occur a great number of equivalent or identical species. This fauna is entirely unlike anything in the Mississippian province of the United States, but some of our western faunas resemble it.

On the northernmost of the Keku Islets about 130 feet of a white, cherty limestone occurs, which is underlain conformably by about 100 feet of shale, sandstone, and conglomerate beds, the latter consisting of cherty pebbles and limestone fragments, which are interstratified with narrow beds of limestone containing numerous fossils. These beds had a N. 10° to 30° W. strike and dip of 30° to 50° NE. Girty in his report notes the following list of genera from the above locality:

Fossils from northernmost of Keku Islets.

Fusulina aff. L. longissima Moell.
Stenopora sp.
Rhombopora sp.
Meekella? sp.
Derbya? sp.
Chonetes aff. C. trapezoidalis Waagen.
Productus aff. P. cora D'Orb.
Productus aff. P. humboldti D'Orb.
Productus aff. P. koninckianus Vern.
Productus aff. P. fasciatus Kut.
Productus aff. P. tartaricus Tsch.
Productus aff. P. lineatus Waagen.
Productus semireticulatus Martin.
Productus aff. P. jakovlevi Tsch.
Productus n. sp. aff. P. tuberculatus Moell.
Productus sp.
Marginifera aff. M. juresanensis Tsch.
Spirifer cameratus Tsch., non Martin?
Spirifer arcticus Houghton?
Spiriferina aff. S. pyramidata Tsch.
Squamularia sp.
Pugnax aff. utah Marcou.
Rhynchopora aff. R. geinitziana Tsch.
Rhynchopora aff. R. nikitini Tsch.?
Camarophoria aff. C. purdoni Davidson.
Camarophoria aff. C. superstes Vern.

Streblopteria sp.
Aviculipecten aff. A. mccoyi M. and H.
Aviculipecten, 2 sp.
Pinna? sp.
Schizodus sp.
Capulus sp.
Straparollus sp.
Bulimorpha? aff. B. peracuta M. and H.
Pseudomelania sp.
Loxonema aff. L. subgracilis Netch.
Turbonellina aff. T. chatzepovkensis Kak.
Pleurotomaria. 2 sp.
Bellerophon sp.
Medlicottia aff. M. ornignana Vern.
Leperditia sp.

This fauna belongs to the lower series of the Gschelian or upper Carboniferous.

A few miles west of the Keku Islets the Carboniferous limestone is again found on Kuiu Island along the east short of Saginaw Bay. It forms a belt of outcrops from Cornwallis Point nearly to the head of the bay. The peninsula forming the east side of the bay is in an area of moderate folding where deformational forces have exerted a minimum influence, so that the rocks are but slightly metamorphosed and the preservation of the fossils is exceptionally good. At the north end of Halleck Harbor, near the entrance of Saginaw Bay, the axis of a gentle fold, apparently only 600 or 800 yards across, lies near the middle of the cove. The dip of the beds in this fold varies from 8° to 45°. Another small fold may be seen just west of Halleck Harbor. The trend of these folds is variable, but is generally northwesterly and southeasterly. The section exposed in Halleck Harbor is very similar to that shown on Keku Islets. Beds of white cherty limestone 450 feet or more in thickness overlie a series of black, carbonaceous shales, calcareous sandstones, and conglomerates with an exposed thickness of 125 feet. This section is of special interest because the faunas present in its upper and lower divisions represent respectively the upper and lower series of the upper Carboniferous formations. In the lower beds of the section, which is exceptionally rich in genera, Girty identified the following forms:

Fossils from Halleck Harbor, Kuiu Island; lower division of upper Carboniferous.

Fusulina aff. F. longissima Moell.
Crania sp.
Schizophoria? sp.
Derbya aff. D. robusta Hall.
Chonetes sp.
Chonetes aff. C. trapezoidalis Waagen.
Productus aff. P. humboldti D'Orb.
Productus aff. P. porrectus Kut.
Productus aff. P. semireticulatus Martin.
Productus aff. P. schrenki Stuck.
Productus cora D'Orb.
Spirifer aff. S. ufensis Tsch.
Spirifer cameratus Tsch., non Martin?
Squamularia n. sp.
Martiniopsis sp.
Rhynchopora aff. R. geinitziana Tsch.
Dielasma sp.
Streblopteria sp.
Aviculipecten aff. A. mccoyi M. and H.
Aviculipecten, 2 sp.
Entolium aff. E. aviculatum Meek.
Solenopsis? sp.

In the overlying limestone beds belonging to the upper series Girty reports the following:

Fossils from Halleck Harbor, Kuiu Island; upper division of upper Carboniferous.

Zaphrentis? sp.
Crinoid fragments.
Stenopora sp.
Streptorhynchus aff. S. pelargonatum Schloth.
Chonetes, 2 sp.
Productus aff. P. timanicus Stuck.
Productus aff. P. aagardi Toula.
Productus aff. gruenewaldti Stuck.
Productus aff. P. humboldti D'Orb.
Productus aff. P. mammatus Keys.
Productus aff. P. lineatus Waagen.
Productus aff. occidentalis Newberry.
Productus sp.
Spirifer aff. S. alatus Schloth.
Spirifer aff. S. blasi Vern.
Spirifer articus Houghton.
Spirifer n. sp. aff. S. marconi Waagen.
Spirifer aff. S. dieneri Tsch.
Spiriferina aff. S. cristata Schloth.
Squamularia sp.
Cleipthyris sp.
Camarophoria margaritovi Tsch.
Camarophoria aff. C. purdoni Davidson.
Rhynchopora aff. R. nikitini Tsch.
Rhynchopora aff. R. geinitziana Tsch.
Dielasma sp.

Corresponding fauna have been found in the limestone beds at Taku Harbor on the mainland in the Juneau district, and in the Ketchikan district limestone beds rich in coral fragments and probably of the same horizon occur at the head of George Inlet.

These two localities in the mainland belt are included in a succession of argillites and crystalline schists which are closely folded and highly metamorphosed and form a band from 5 to 15 miles wide striking northwesterly along the southwest flank of the Coast Range intrusives. These metamorphic strata, which are called the "Ketchikan series"[a] in this province and in the Juneau district the "Schist band,"[b] probably include many different formations which, however, can not be defined because of the complexity of structure and the metamorphism developed in them.

At the Taku Harbor locality, 25 miles south of Juneau, specimens of *Productus* aff. *P. gruenewaldti* Krot. were found by E. M. Kindle in 1905 in a much-altered limestone at the base of the slate-greenstone band defined by Spencer.[c] They determined definitely the age at this point as upper Carboniferous. At the George Inlet locality a large collection of fragmentary corals was gathered at a point on Revillagigedo Island and submitted to E. M. Kindle, who reports the following:

No. 966. Point on southeast side of George Inlet 10 miles from its head, Revillagigedo Island.—The fossils from this point comprise only crinoid stems, which, however, are so abundant as to make up a large portion of the rock. Crinoid stems can not ordinarily be used for correlation. However, their great

[a] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902, p. 42.
[b] Bull. U. S. Geol. Survey No. 287, 1906, pp. 16-17.
[c] Idem. pp. 18-19.

abundance here seems to justify a surmise that they very probably represent a Carboniferous horizon. Crinoids in such abundance as is shown by these specimens occur in very few places, if anywhere, outside of Carboniferous horizons. In the absence of other evidence the horizon represented may be referred tentatively to the Carboniferous.

A third fossil locality in this mainland belt was discovered by L. M. Prindle at a point just north of the town of Wrangell. The inclosing rock strata were argillaceous black slates, and the fossils contained were so poorly preserved that definite paleontologic statements could not be made in regard to them. They were referred to G. H. Girty for examination, who submits the following report:

The fossils in question consist of two specimens of pelecypod shells, both apparently belonging to the same species. In their present state the ultimate generic characters are concealed, and, though it is sometimes possible to determine the genus satisfactorily without these characters, as by some peculiarity of shape, such determination is not possible with the present examples. In fact, even specific characters have been more or less obscured and changed, so that these shells might belong almost equally well to several genera whose range and geologic age, so far as paleontologic evidence is concerned, might be almost anywhere from Devonian to Recent. If Paleozoic, I would feel disposed to refer them, by reason of their shape and sculpture, to the genus *Edmondia*, though such a reference would be little more than a surmise. The range of *Edmondia* is practically restricted to the Devonian and Carboniferous. It is with sincere regret that I submit a report as unsatisfactory as I know this must be, but I feel that the evidence would not justify a stronger or more definite opinion.

In view of the comparatively weak paleontologic and stratigraphic evidence bearing on the precise age of these argillites and crystalline schists, it is possible that their period of deposition extended even beyond the Carboniferous period into the Triassic, especially when the extensive development of Triassic strata to the south in British Columbia, as described by G. M. Dawson,[a] is taken into consideration. The evidence thus far gathered, however, indicates Carboniferous age for the greater portion of these crystalline schists and argillites. Besides their distribution along the mainland and adjacent islands, they are developed widely on Prince of Wales Island and to a limited extent on Kupreanof Island.

The most recent Paleozoic rocks in this province are upper Carboniferous lava and tuff beds interstratified with beds of black slate. (Pl. VII, *A*.) This age determination is based on their structural relations to the older and younger rocks and on the fact that the upper Carboniferous strata at Taku Harbor underlie the greenstones with apparent conformity. These beds in the Juneau district are described at length by Spencer as the "slate-greenstone band." These strata trend in many places parallel to the older limestones and schists and have been subjected to the same dynamic forces that

[a] Geol. Nat. Hist. Survey Canada, 1879-80, pp. 1-177 B.

A. INTERSTRATIFICATION OF SLATE BEDS AND GREENSTONES, NORTH END OF CLEVELAND PENINSULA

B. FLAT-LYING GRAYWACKE BEDS, NORTH END OF SAN FERNANDO ISLAND.

produced the northwest-southeast system of folds. The beds are in many places steeply tilted either to the southwest or to the northeast, although local variations in strike and dip are common. The total thickness of these strata has been estimated to be over 4,000 feet. They occur principally along the outer border of the mainland belt, but they also form a smaller belt along the seaward shores of Chichagof and Baranof islands and on the west coast of Prince of Wales Island.

As a whole the greenstone members of this slate-greenstone formation predominate over the slate or the sedimentary beds, but the relative proportion varies from place to place. The variation is attributed to the inequality in distribution of the lava flows and tuffs. In the beds themselves the igneous and sedimentary material is intimately associated in varying amounts and grades from altered andesitic lavas and tuffs to purely sedimentary beds (Pl. VII, A).

In the Ketchikan and Wrangell districts the slates and greenstones can be traced from Dixon Entrance to Cape Fanshaw, including Duncan Canal, Cleveland Peninsula, and Gravina Island. They as well as the crystalline schists to the northeast are important mineral-bearing formations.

Limestone and conglomerate beds of a Carboniferous horizon still higher than that at Saginaw Bay or Taku Harbor occur at Pybus Bay on Admiralty Island and have been recently reported from Hamilton Bay on Kupreanof Island.[a] The relation of these beds to the slates and greenstones above mentioned is not known, but in the stratigraphic column on pages 34, 35 they have been provisionally placed above the slates.

MESOZOIC STRATA.

The formations in the Ketchikan and Wrangell districts that have been referred to the Mesozoic era have no fossils, and their classification is therefore based entirely on structural and petrographic evidence. The only Mesozoic fossil found was in a loose fragment of limestone picked up at the head of Hamilton Bay. It was identified by T. W. Stanton as *Pseudomonotis subcircularis* (Gabb), which is characteristic of a horizon near the top of the upper Triassic. No similar rock was seen in place and the source of the specimen is unknown, but it probably represents Triassic beds in southeastern Alaska and thus shows that deep-sea conditions existed along the coast at that period.

So far as known, the Coast Range intrusives, which occupy about half the land area of southeastern Alaska, invaded the bedded forma-

[a] Mr. W. W. Atwood visited this locality in May, 1907, and reported the Hamilton Bay occurrence.

tions during the early part of the Mesozoic era. These intrusives are discussed under the heading "Igneous rocks."

On the southern end of Prince of Wales Island is a succession of andesitic flows, conglomerates, and tuffs, which grade into a series of graywackes or indurated sandstones. These have been considered Mesozoic because of their structural and petrographic relations to the older rocks. In this complex, basaltic and andesitic flows are intercalated with the tuffaceous beds, and both flows and tuffs alternate with the sedimentary slates, graywackes, and conglomerates. They are readily distinguished from the greenstones by the wide difference in composition and texture of the interstratified beds and by their predominant reddish color. A fine, compact, green tuff is usually overlain by an andesitic lava with numerous large phenocrysts, which in turn is overlain by a basaltic lava or a red lava conglomerate. The greenstone beds, on the other hand, vary little in composition and where massive, augite crystals form the phenocrysts.

On the south end of Prince of Wales Island the andesitic flows and conglomerates overlie at several points the eroded surfaces of granitic intrusive masses, and numerous dikes of the andesite intrude these older granites. Pebbles and fragmentary masses of the granite were observed in the tuffaceous conglomerates, showing clearly that the andesites are younger than these masses of granitic rock. The granites at this point were more altered and contained more shearing planes than are usual in the Coast Range intrusives, and they may represent a batholith intruded before or during the earliest stages of the period of the Coast Range granitic invasion. The graywackes overlying the andesites are compact and indurated, but do not show a schistose development (see Pl. VII, *B*); the numerous slate fragments prominent in the rocks of the Sitka series to the north are absent, and beds of slate are less common. Pebbles of granodiorite, quartz, andesite, and graywacke are plentiful in the conglomerates. These beds, as a whole, though tilted at steep angles and folded, have not suffered the intricate folding and metamorphism shown in the older rock beds including the Sitka series. No fossil evidence was found in these beds, but from the above facts it is reasonable to suppose that they occupy a position in the stratigraphic column between Triassic and upper Cretaceous.

To the north, on Admiralty Island,[a] in Pybus Bay, slaty limestone and conglomerate beds, containing the fossil forms *Aucella crassicollis* and *Aucella piochii*, overlie the upper Carboniferous beds unconformably. These lower Cretaceous strata may represent the same horizon as the graywacke conglomerate beds mentioned above, though in the latter no fossils were found.

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[a] Bull. U. S. Geol. Survey No. 287, 1906, p. 144.

TERTIARY STRATA.

The Tertiary beds, as shown in previous reports,[a] are widely distributed along the North Pacific coast, though their total thickness is comparatively small. In the Wrangell district they are locally developed at Hamilton Bay on Kupreanof Island. On Prince of Wales Island they occupy but a small local area at Coal Bay, a southern arm of Kasaan Bay.

The Tertiary beds comprise an assemblage of conglomerates, sandstones, and lignitic coal seams, together with volcanic lava flows overlying and interstratified with the sediments.

The occurrence of the beds at low elevations, surrounded in places by mountains of Paleozoic rocks, indicates that the Tertiary sediments were deposited in lakes or shallow embayments alternating with swampy land, on which the vegetation of the coal beds accumulated. Erosion and movement of the older rock beds probably caused the local basin-like depressions. The beds are still soft, friable, and unmetamorphosed, though they are in many places fractured and tilted to some extent. However, the deformation of the original horizonal structure is slight when compared with that of the underlying strata. The conglomerates of the Tertiary consist essentially of slate fragments with pebbles of granite, greenstone, and limestone, many of them measuring several inches in diameter. These alternate with beds of sandstone and shale and with them have a general southerly dip of from 5° to 10° and an easterly strike. Sandstone is the predominant rock of the Tertiary. It contains less quartz than usual and a large amount of rock fragments, such as slate and limestone, rather than of mineral fragments. The beds are gray to brownish and loosely consolidated, many of them showing cross-bedding. The shale beds contain a high percentage of clay and bituminous matter, and in them are numerous fossil plant leaves.

Coal occurs in beds 3 inches to 3 feet thick, interstratified with seams of carbonaceous shale and sandstone. It varies from a black lignite to a bituminous coal, but nowhere in southeastern Alaska has it been found in commercial quantities.

The gray shales of this sandstone series contain an abundant flora, which F. H. Knowlton considers as probably of Kenai age (upper Eocene). A collection from Hamilton Bay was submitted to him and the following species were identified:

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[a] Dall, W. H., Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896; Brooks, A. H., Coal resources of Alaska: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902.

Fossil plants from Hamilton Bay, Alaska.

Sequoia langsdorfii (Brgt.) Heer.	Quercus sp. nov.
Sequoia nordenskioldi? Heer.	Laurus sp.
Taxodium distichum miocenum Heer.	Populus sp.
Juglans nigella Heer.	Alnus sp.
Ulmus sp.	Castalia? sp. nov.

A succession of basaltic lava flows, in which columnar jointing is a well-developed and characteristic feature, overlies the coal-bearing strata, and occupies extensive areas on the northeast end of Kuiu Island and the entire southern shore of Kupreanof Island. These lava beds, with occasional strata of conglomerate, sandstone, and tuff, have a total thickness estimated at 2,000 feet. In the lower portions of the series exposed along the shores of Port Camden on Kuiu Island narrow seams of impure coal were observed, and fossil plant leaves were collected from the interstratified sandstone beds. Beds of coarse conglomerate with pebbles mostly of volcanic material also occur, grading into the sandstone beds. Structurally these beds are inclined only a few degrees from the horizontal and have suffered little or no deformation since their deposition.

A collection of plant remains from fine-grained gray argillaceous sandstone, interstratified with the lava conglomerates, was made at a point east of Port Camden, 3 miles south of the entrance. Knowlton states in his report on this flora that the material was ample and very finely preserved and determines the age as Kenai. The plants identified are:

Fossil plants from Port Camden, Alaska.

Sequoia langsdorfii (Brgt.) Heer.	Lastræa stiriaca (Unger) Heer.
Taxodium distichum miocenum Heer.	Corylus macquarrii (Forbes) Heer.
Taxodium olriki Heer.	Juglans nigella Heer.

The above determinations and the stratigraphy indicate that the beds at Hamilton Bay and at Port Camden represent about the same horizon.

The Tertiary beds observed at Coal Bay on the east side of Prince of Wales Island are very limited in extent and apparently occupy a local basin formed in the underlying Paleozoic rocks.

An exposure of these beds one-third of a mile up the creek at the head of Coal Bay showed the following section:

Section of Tertiary beds at Coal Bay, Alaska.

	Ft.	In.
Coarse, gray to brownish sandstone	4	0
Blue, fine-grained sandstone	5	0

The strike of these beds was N. 60° W., and the dip 15° NE. The coal is a brownish-black lignite of light weight and contains occa-

sional grains of amber. It is said to burn poorly, leaving much ash. Two shafts, one 20 and one 40 feet deep, have been sunk at this locality without satisfactory result.

Pliocene beds like those which occur along this coastal belt farther northwest, at Lituya Bay, and gravel beds containing marine shells, which are present at points in the Juneau district, have not been observed in the Ketchikan or Wrangell districts.

The most recent rocks are the basâltic lava flows along the mainland and on Revillagigedo Island, in the Ketchikan district. These are described in the following pages under "Igneous rocks."

IGNEOUS ROCKS.

The igneous rocks include (1) the intrusive masses, as the granitic batholiths, gabbros, and peridotites which invade the sedimentary rock beds, (2) the extrusives, or those which represent surface lava flows during the different geologic periods, as the greenstones, andesites, and basalts. The most abundant and important of the igneous rocks are the Coast Range granitic intrusives, which occupy about one-half of the aggregate land area of these two districts.

COAST RANGE INTRUSIVES.

GENERAL DESCRIPTION.

The Coast Range massif, as it has been defined by Dawson, is not of the same composition throughout but is composed of different kinds of igneous rocks ranging from granite to diorite and even gabbro; quartz-hornblende diorite or tonalite being the predominating type. The most noteworthy feature of the entire Coast Range mass of intrusives is their general uniformity in texture and their continuity. The variations across the range are apparently not so gradual as those along its trend. The Coast Range massif consists of many separate interlocking batholiths, or batholiths within batholiths, intruded at successive epochs but during the same general period of irruption. In the southern part of Alaska, especially in the Unuk River, Stikine River, and Portland Canal sections, the contacts between the different batholiths are less sharp than in the northern Skagway cross section. The geologic evidence indicates that the granite in the southern region was intruded into more deeply buried rocks than that in the northern region, and this fact may acount in part for the difference in contacts. It is probable that under such very deep-seated conditions, owing to the general similarity in composition between the masses, local gradations would take place at the contacts and obliterate the sharp lines of demarcation which would result if the superheated intrusive masses were nearer the surface and in contact with cooler surrounding rock masses.

In this portion of the Alaskan Coast Range rapid gradations from one type to another occur and indicate in many ways intrusion within intrusion besides variation due to differentiation and assimilation. Naturally it is not probable that intrusion was or could be accomplished over such a wide area at one time and by one huge magma. For the gradual relief of strains and stresses due to the transfer of so much material and also for the action of a viscous magma the lapse of considerable time must be assumed. Furthermore, all conceptions of the mechanics of mountain building involve the consideration of a complicated system of forces, which require nice adjustment to be brought into equilibrium; local differential forces of compression or tension must be relieved by changes in relative position, while the larger orogenic tangential or radial forces must also find eventual expression and relief in mass transfer, as by batholithic intrusions and orogenic uplift. We have, then, to deal with a dynamic system tending toward static equilibrium, and therefore the time element is involved in our general conceptions of the mechanics of the problem.

Several interesting facts were observed in the field which have a bearing on the general problem of the explanation of the Coast Range intrusion. Jointing planes and sheeted zones are often well marked in the granodiorite, and trend northwest with steep northeasterly dips. In the southern part of southeastern Alaska, particularly along the shores of Behm Canal, pegmatite and aplite dikes form an intricate network and mesh of white strands along the outer portions of the granodiorite massifs and in the adjacent schists, but in the central parts of the batholiths they are practically absent. Several systems of such dikes were observed; the oldest set occurs as thin, narrow bands following master joint planes and standing out as ribs above the surface of the more easily weathered granite; a second set is wider and usually perpendicular to the first; while a third and still later set, which is distinctly irregular, apparently fills the largest fracture cracks. This condition suggests that during the last period of magmatic activity the rock masses underwent considerable movement and fracturing and were brought nearer the surface. That still later differential movement has taken place is evident from the minor faulting of the pegmatite dikes themselves. At a distance this schist complex with its innumerable pegmatitic dikes, resembles a breccia, the white pegmatites acting as interstitial cement for the dark angular fragments and blocks of schist.

The sedimentary rocks flanking the Coast Range batholiths in this region are folded closely near the contact and more openly at a distance, so that, though their general trend is parallel to the range, their dip is extremely variable, ranging from northeasterly to southwesterly at all angles. Such dips, however, do not exist throughout southeastern Alaska, for northward from Behm Canal,

in the Wrangell and Juneau districts, the strike and dip become more and more constant, the schists are more typically developed, mineralization along certain bands is more pronounced and sharp, and closed and overturned folds appear to be the rule. The prevailing dip is steeply northeast into the mountains, and the strike is parallel to the range. The economic bearing which this change in structure has had on the formation of ore bodies is interesting and is discussed on page 77.

Petrographically the field term granite, which is generally used to designate the Coast Range intrusives, applies to only a small part of the rocks. The prevalent type is less siliceous and ranges in composition from granodiorite to diorite and gabbro, with hornblende and biotite as colored constituents and titanite as a frequent visible accessory component. As a general rule hornblende appears more abundant near the coast, while biotite predominates near the inland border of the Coast Range batholiths. Near the coast also the granite is usually more gneissoid in aspect, especially along Behm Canal, and contains abundant inclusions of the intruded schist near its contact. These inclusions become more and more coarsely crystalline away from the contact, until finally they resemble basic or acidic differentiation products and are gradually lost sight of. A characteristic feature in this region is that while aplitic and particularly pegmatitic dikes are extremely abundant near the western contact of the granite and form an intricate network in the adjoining schist areas, they are rare and practically absent in the central parts of the range. On its eastern flanks numerous salic dikes occur, but they are far less abundant than on the coastal side. The absence of minette and similar basic differentiation dike products is noteworthy and may be due to the fact that the dikes are pegmatitic rather than aplitic and, therefore, are not, strictly speaking, magmatic differentiation products in the usual definition of the word.

The importance of the pegmatites becomes apparent when the mode of formation from a solution emanating from the intrusive mass is considered. They represent only a small part of the work accomplished by the pneumatolytic solutions of the granite and are convincing evidence of the great volume of pneumatolytic solutions which accompanied the batholithic invasions. The intimate connection of the ore bodies in southeastern Alaska with the intrusive masses has been proved directly in several places and is inferred in a number of the remaining deposits.

AVERAGE COMPOSITION OF THE COAST RANGE BATHOLITHS.

Although the composition of the Coast Range granodiorites varies considerably from point to point, it is desirable to ascertain the approximate average composition of the entire mass. To this end

seven typical specimens were selected from different parts of the range. These specimens were chosen with special regard to their abundance and general distribution throughout the area, abnormal and rare types being disregarded altogether. Each of these specimens was studied in detail under the microscope, and a careful estimate of the relative quantity of each mineral in the rock was made from the thin sections by the Rosiwal method. Although the values thus obtained are necessarily only first approximations, they represent roughly the general mineral content of the Coast Range granodiorite.

The following average mineral composition was thus obtained:

Average mineral composition of the Coast Range intrusive.

Quartz	19.4
Orthoclase	6.6
Andesine ($Ab_{56}An_{44}$)	47.4
Hornblende	7.6
Biotite	11.6
Apatite	.6
Magnetite	.9
Pyrite	.1
Titanite	1.3
Epidote	3.5
Chlorite	.1
Calcite	.1
Kaolin and muscovite	.8
	100.0

The average specific gravity, 2.77, was determined by weighing the hand specimens in air and then in water.

From these data the average chemical composition was calculated by assuming for the hornblende and biotite the compositions of like minerals from a similar rock from Butte, Mont.

Average chemical composition, norm, and classification of the Coast Range intrusive

Constituent.	Per cent.	Molecular ratio.	Norm.			Classification.
SiO_2	61.0	1.017	Q 16.14	16.14	84.26	Class, $\frac{\text{Sal.}}{\text{Fem.}} = 4.78$
TiO_2	1.0	.013	Or 13.32	68.12		Order, $\frac{F}{Q} = 4.22$
Al_2O_3	17.5	.171	Ab 27.78			
Fe_2O_3	1.6	.010	An 27.02			Rang, $\frac{K_2O' + Na_2O'}{CaO'} = 0.82$
FeO	2.7	.038	Di 4.81	10.56	15.52	Subrang, $\frac{K_2O'}{Na_2O'} = 0.45$
MnO	.1	.001	Hy 5.75			
MgO	2.4	.060	Mt 2.32	4.29		
CaO	6.9	.123	Il 1.97			
Na_2O	3.3	.053	Ap .... .67	.67		
K_2O	2.3	.024				
H_2O	.9	.050				
P_2O_5	.3	.002				
	100.0					

This chemical and mineral composition places the rock in the family of the quartz diorites, of the type tonalite according to the usual classification. In the new quantitative classification of Cross, Iddings, Pirsson, and Washington the rock is dosalic, dosalone quardofelic, alkalicalcic, and dosodic, and belongs in Class II, order 4 (austrare), rang 3 (tonalase), and subrang 4 (tonalose). In short, it is tonalose of the ordinary type.

The amount of titanite is unusual and is characteristic of many of the Coast Range intrusives. The highly lustrous, well-shaped crystals of this mineral glisten in the sunlight and attract the attention of the most casual observer. The hornblende occurs usually in dark prismatic crystals, noticeable for the excellent prismatic cleavage and the lack of terminal faces. Many biotite flakes are hexagonal and deep brown in transmitted light. A few apatite crystals are visible to the unaided eye, but this mineral occurs generally in fine hexagonal crystals of microscopic dimensions. Pale green veinlets of secondary epidote, which follow fracture planes in the granodiorite, are not rare.

These even-grained rocks usually have the normal, sharply defined, granitoid texture. However, gradations to holocrystalline porphyritic phases, due to the superior development of the feldspars, occur. Gneissic structure is common near the western margin of the Coast Range belt. In some places the development of gneissic structure in the granite has been so far advanced and the recrystallization of the neighboring invaded sediments to gneiss has been so thorough, that it is difficult to define the precise limits of the original intrusive granite.

CONTACT METAMORPHISM.

That the immense Coast Range batholiths are not surrounded by evident contact aureoles of similar proportions has been frequently noted. Contact minerals have been observed only rarely and are of local significance.

In metamorphic alteration those changes in mineral combinations take place which tend to produce under the given conditions more stable equilibrium throughout the system. It is probable that at many points along the western flanks of the batholiths the schists now visible were so deeply buried at the time of intrusion that the invading granite did not alter them so materially as to produce wide contact change. Strata nearer the surface at the time of intrusion should show more pronounced alteration from the magmatic solutions and the heat. Although the strata directly above the massifs have long since been removed by erosion, an observer approaching the contacts from the southwest finds that distinct changes in the sedimentary rocks are generally noticeable, especially in the southern

portion of southeastern Alaska. The prevailing argillites become more visibly crystalline, and at many points, especially in the Wrangell district, new minerals, andalusite and staurolite, occur. From the coast of Behm Canal to the western contact of the Coast Range massif the invaded sedimentary rocks change from slates and argillites to phyllites and mica schists and in some places near the contact to gneiss. The many types of hornfels are rare, and spotted schists do not form an integral part of the complex. The strata are intensely folded and were undoubtedly deeply buried at the time of the granite invasion. Deep-seated metamorphic forces were already active and had undoubtedly heated and altered the rocks to such an extent that the granitic intrusion did not disturb their equilibrium greatly; its chief effect being to accentuate the processes of crystallization already in force and to increase their power rather than to replace them by others. At the contact itself, the granite frequently contains inclusions of the schist, which have usually become more coarsely crystalline, though their original outline is still well preserved. This coastal strip exposed along Behm Canal, whose contact with the granite can be traced only with difficulty, offers, therefore, an excellent example of the metamorphic changes produced by deeply buried granite.

It is significant that in these deep-seated schists and gneisses near the granite contact no ore bodies of consequence have been found, while rocks farther away from the granite and nearer the surface during its invasion in many localities show traces of contact metamorphism, as in spotted schists, and contain valuable metalliferous deposits. The folded character and lack of uniform structure in the strata near the granite contact may account in part for the absence of commercial ore deposits, since they offer no lines along which concentration could easily take place as in the isoclinal schists of the Juneau district farther north. Within the granite area itself are occasional belts of included sedimentary rocks in a highly metamorphosed condition. They vary from argillites to mica, hornblende, and calcareous schists of various types, even marble, and occur in long bands, intensely folded. They still preserve in general their northwest trend, parallel to the course of the range, and their steep northeasterly dip and are walled in by great mountain masses of intrusive granite. In the region about Glacier Bay the granite contains numerous inclusions of schists arranged irregularly and showing beyond question that cleavage had been superinduced upon them before the granite intrusion. From general structural relations in the Juneau district Spencer[a] has concluded that the schistosity and steep isoclinal dip to the northeast characterized the

[a] Spencer, A. C., Bull. U. S. Geol. Survey No. 287, 1906, pp. 13–15.

schists before the entrance of the batholiths and controlled at the time of invasion the form of intrusion by offering parallel lines of least resistance along the planes of schistosity. So far as the writers' experience in the Juneau district goes, this conclusion is justified by the facts and is further strengthened by the exposures in Glacier Bay.

The included schist belts within the Coast Range are usually not wide, and more appear near the mountain tops than at sea level. They can be traced up the exposed cliffs and bare mountain sides for 4,000 to 6,000 feet. They are usually intensely mineralized with sulphides, especially pyrite, and near the mountain crests show abundant evidence of contact metamorphism, formation of garnetiferous rocks, etc. These roof pendants, as R. A. Daly[a] has aptly named them, were directly above the intrusive mass and were evidently in the most favorable position to be affected by magmatic waters and heat escaping from the intrusives, so that they now are the most heavily mineralized bodies.

The character of the invaded sedimentaries east of the inland border of the granite is noticeably different. The slates and sandstones are less altered and typical schists and sandstones are rare. Folding and particularly faulting are common and characteristic of the entire complex (Pl. VIII, *A*). The granite contact line is sharp and frequently traverses the bedding planes of the intruded strata. Although its general trend is parallel to the Coast Range, the actual line of contact exposed in the Unuk River section undulates locally and cross-cuts the strata at variable angles. The intruded rocks are often indurated and heavily mineralized with sulphides near the contact and show evidence of metamorphism by the intrusives.

By comparing the metamorphic effects of the intrusive granite along its western and eastern flanks in the latitude of the Ketchikan district decided differences are apparent. On the coastal side the metamorphism near the contact is usually of the deep-seated type; gneisses and schists predominate and are cut by innumerable pegmatite dikes ramifying from the granite. Mineralization by sulphides is not pronounced near the contact. Farther west, at some distance from the contact, evidences of contact metamorphism increase, the degree of mineralization also increases, and valuable ore bodies have been discovered within this zone in the Ketchikan district. Along the eastern border of the granite, on the other hand, the metamorphism is of the contact type, argillites and slates predominate and are often indurated and heavily impregnated with sulphides. Well-defined ore bodies have been found near the granite contact. The geologic interpretation of these data indicates clearly that the rocks

[a] Am. Jour. Sci., 4th ser., vol. 15, 1903, pp. 269-298; vol. 16, 1903, pp. 107-126.

east of the massifs were less deeply buried at the time of intrusion than those on the coastal side. In other words, the inland rocks were then above the zone of deep-seated metamorphism or rock flowage, and were, therefore, profoundly affected by the invading intrusives and accompanying pneumatolytic solutions. Furthermore, the mineral-bearing solutions emanating from the granite encountered new conditions of temperature and pressure on entering the adjacent sedimentary rocks and deposited, as supersaturated solutions in their new environment, a portion of their dissolved contents, especially the metallic sulphides and silicates.

Although in such a large belt the phenomena of contact metamorphism are not so pronounced and concentrated as in the contact aureole of a small intrusive boss, they are equally as varied, though more extensive and on a larger scale. It has frequently been observed that in a small contact aureole different contact minerals occur at different distances from the intrusive mass, and that under similar conditions an evident relation exists between a given contact mineral and its distance from the invading rocks; and in a general way this law apparently holds true for this eastern contact zone of mineralized sedimentary rocks.

DIKE ROCKS AND MINERALIZATION.

The various dike rocks which accompany and intrude the Coast Range batholiths may be arranged in two groups, the first containing the pegmatites, aplites, alaskites, granite porphyries, and allied rocks, and the second containing the lamprophyres of several types, diabases, and other basic intrusives. Although interesting from a petrographic standpoint, these rocks have little commercial value and, with the exception of the pegmatites and aplites, are not of great importance (Pl. VIII, *B*).

The pegmatites are not of the usual type, their feldspars being almost invariably oligoclase and not orthoclase or microcline. They are usually pure white and coarse grained and do not contain accessory constituents in abundance. In the central parts of the Coast Range the pegmatites and, in fact, all dike rocks are rare, but along the western margin and adjacent sedimentary rocks hardly a cubic meter of country rock is visible which is not pervaded by them. As noted previously, the pegmatites are not all of the same age, but have been formed at different periods, the older dikes following definite jointings and fracture planes in the country rocks. The occurrence of these innumerable pegmatites along the margin of the Coast Range batholiths is a significant indication of the immense quantities of pneumatolytic solutions given off by the invading crystallizing magmas. In the region of most intense development of

A. CLOSELY FOLDED AND HIGHLY CRYSTALLINE SCHISTS ADJACENT TO THE COAST RANGE INTRUSIVES, BRADFIELD CANAL.

B. APLITE AND PEGMATITE DIKES CUTTING THE CRYSTALLINE SCHISTS, BRADFIELD CANAL.

pegmatites, as in the Behm Canal area, the amount of ore deposition was slight and no ore bodies of importance have been discovered.

Farther away from the granitic intrusion magmatic solutions given off by these igneous masses encountered conditions more favorable to the precipitation of the metallic sulphides carried in solution and deposited them at such points. As a result the argillites and slates a few miles west of Behm Canal, as on Cleveland Peninsula and Revillagigedo Island, are very heavily impregnated with sulphides, especially cubes of pyrite. The total amount of sulphides in these rocks is enormous and would be difficult to explain otherwise than as due to the influence of the Coast Range intrusives. An unfavorable result of this widespread mineralization has been to disseminate the values over large areas and to render the whole of little commercial importance. In certain instances, however, sufficiently intense concentration has taken place within small areas and produced commercial values.

As further evidence of the important part played by the Coast Range intrusives, it may be cited that the ore deposits are apparently all later than these intrusives; that occasionally the pegmatite dikes in this area pass gradually into quartz veins, and that the evidences of contact metamorphism and the development of contact minerals such as staurolite and andalusite are not rare in the heavily mineralized rock belts. Nearer the Coast Range the rocks now exposed were at the time of intrusion deeply buried and therefore extremely hot and under considerable pressure. The solutions, escaping from the granite and entering this complex, encountered conditions not greatly unlike those within the crystallizing granite itself, and sulphide deposition was slight. On reaching the zone of less pressure and colder rock formations, however, the ascending solutions met with new conditions, favorable to the precipitation of sulphides and minerals closely allied to those of ordinary contact metamorphism, where heat and magmatic solutions are the prime agents of metamorphism.

OTHER INTRUSIVES.

Dikes of diabase, porphyrite, and felsite are common throughout the region and cut all of the older rock strata. Some of these have been indicated on the geologic map. The importance of these rocks, however, is relatively small when compared with the Coast Range intrusives and their accompanying dike rocks which have already been discussed. For the most part these dikes may be considered as the intrusive forms of the greenstones, andesites, and basaltic lavas, described in the following pages. Diabase, which is the most widely distributed dike rock in the region, occurs cutting the ore bodies in many places. It usually has a fine-grained ophitic texture, is dark

green, and consists essentially of altered plagioclase feldspar, together with basaltic hornblende largely altered to uralite. Both magnetite and pyrite are generally present in disseminated grains. The porphyrites, which may be regarded as the dike rocks of the andesitic lavas, are characterized by their porphyritic texture, by their light-green color, and by large plagioclase feldspar phenocrysts contained in a finely crystalline groundmass. These dikes, though less common than those of diabase, are also of more recent intrusion than the ore deposits. These dikes are numerous along the shore exposures where they cut the Paleozoic strata and the granitic intrusives.

Dikes of felsite have been noted in only a few places, principally on Kasaan Peninsula, where they are associated with the copper deposits. They are usually brownish and finely crystalline, and are composed essentially of feldspar, many crystals of which form large phenocrysts. They were evidently of later intrusion than the ore deposits, though ore was contained in them in places. Narrow dikes of basalt were observed on Kasaan Peninsula and at other localities. They are usually black, finely crystalline, and porphyritic, and vary widely in composition. The basalts are the most recent intrusive rocks.

EXTRUSIVES.

GREENSTONES.

The upper Carboniferous extrusives mentioned in the foregoing pages are represented essentially by tuffaceous strata and lava flows, which have been generally metamorphosed and rendered schistose, their original mineral constituents having been replaced to large extent by secondary products. Because of this alteration the former character of the rock has in most places been obliterated, but elsewhere their texture and mineral content mark them as igneous rocks. The interstratification and the intermingling of the igneous material with the black slates indicate that most of the igneous material, composed of tuffs and some agglomerates, resulted from volcanic outbursts. Lava flows also occur, but are less frequent.

The term greenstone, which is a convenient field name, has been applied to the rocks of this type, both schistose and massive, and includes the intrusive as well as the extrusive forms. They are all intensely metamorphosed, have a greenish cast, and range in composition from altered andesites and andesitic tuffs to basalts and altered gabbros.

On Cleveland Peninsula and in the neighborhood of Ketchikan, the greenstones are roughly bedded and conform to the general structure of the neighboring formations. A close study reveals layers varying in composition and coarseness of crystallization, and a few

beds of amygdaloidal structure, showing the original vesicular nature of the rock. Angular breccias also occur containing fragments of greenstone material. All these features are such as would be caused by a succession of volcanic flows and outbursts, and their igneous origin is thus well established.

In the massive flows are numerous phenocrysts of pyroxene, usually less altered than the groundmass, which is always so decomposed that in many places the original nature of the rock can not be definitely determined. Wherever it is less altered and the original texture is still apparent, considerable amounts of plagioclase feldspar and augite phenocrysts are present and the lavas have the typical features of altered andesites. By processes of metamorphism the augite and plagioclase components of the original rock have been obliterated and replaced by green amphibole, biotite, chlorite, sericite, feldspar, epidote, zoisite, calcite, quartz, and other secondary minerals. The beds of tuff and agglomerate are usually intermixed with much sedimentary material and gradations to purely sedimentary beds may often be observed. Because of subsequent alteration the original clastic texture of the tuffs is rarely apparent.

In their most altered form the greenstone schists are fine grained and composed largely of chlorite, calcite, and secondary hornblende giving the rocks a dark-green color. These schists, where permeated by mineral-bearing waters, contain considerable amounts of pyrite, and in several places have been bleached to a light yellow, as may be seen on Gravina Island and Cleveland Peninsula.

As shown on the general geologic map, the greenstones are distributed along the mainland belt including Gravina Island, Cleveland Peninsula, and Duncan Canal; they are also well developed along the shores of Hetta Inlet and on Shukwan Island. The greenstones are irregularly involved with the Carboniferous slates, limestones, quartzites, and schists, having been folded and compressed with them, and are considered to be essentially of the same age.

ANDESITES.

The extrusive rocks provisionally referred to the Jura-Cretaceous period are made up of lavas and tuffs like those of the upper Carboniferous. These extrusives include altered andesites, hornblende porphyrites, quartz porphyrites, and basalt tuffs. With these extrusives are included fragmental or clastic rocks composed of volcanic tuffs, sandstones, and conglomerates. As a whole the lavas are less prominent than the clastic rocks. They occur intercalated with the sedimentary slates and sandstones or graywackes. The original character and manner of deposition of extrusives must have been very similar to that of the older greenstones. They are, however, readily

distinguished from the greenstones by the difference in composition and texture and their dominant reddish color. There is also a difference in the amount of apparent metamorphism of the extrusives of the two eras. The lava and tuff beds of Mesozoic age have not been changed to chlorite or talcose schists and do not show the degree of alteration that is characteristic of the older greenstones. As indicated on the accompanying map, the andesites occupy irregular areas on the south end and along the west coast of Prince of Wales Island, but are not known to occur in other portions of the Ketchikan or Wrangell districts.

BASALTS.

The Eocene period is also characterized by the extrusion of enormous quantities of basaltic lavas and tuffs. The lava beds have been but little disturbed since their extrusion and show little or no alteration. Had they been folded, compressed, and subjected for a long geologic period to the slowly operating chemical and physical agencies which altered the volcanic rocks of Paleozoic and Mesozoic age, they would undoubtedly resemble the latter closely in general character.

The Eocene basalts are porphyritic rocks ranging in color from gray green to gray black and in composition and texture from basic andesite to a normal basalt. Porphyritic textures are usual, but other textural phases have been developed locally. Amygdaloidal structure, with fillings of quartz, chalcedony, calcite, and a zeolite which is probably stilbite, is characteristic of some beds.

They are mostly dark, fine-grained lavas, the only mineral component visible to the unaided eye being phenocrysts of plagioclase and occasionally pyroxene. The microscope further reveals magnetite and rarely olivine and quartz, also a brown zeolitized glass in several of the thin sections. Alternation products are calcite, epidotite, muscovite, chlorite, and serpentine. Many phenocrysts of feldspar show marked zonal structure and grade in composition from acidic andesite to basic labradorite. In the groundmass the plagioclase is usually more acidic. The feldspars occur in larger amounts than the pyroxene.

These extrusives, as indicated on the geologic map, occupy wide areas on Kuiu and Kupreanof islands. The beds are almost flat lying, being tilted at low angles in places. Columnar structure is a characteristic feature and they may be distinguished from other rocks of the region by their usual red surface weathering.

Interstratified among the lowest beds of this succession are strata of rhyolite tuff, breccia, lava conglomerates, and sandstones. At Port Camden, on Kuiu Island, narrow seams of coal interstratified with lavas and sandstone contained fossil plant leaves, which are con-

sidered by paleobotanists to be of Kenai age (upper Eocene). These volcanics overlie the Kenai coal-bearing beds.

Basaltic lavas of postglacial age occupy small areas at various points along the mainland and on Revillagigedo Island. They lie in nearly horizontal beds on the upturned schists and granitic rocks. The massive lava dominates, but narrow beds of tuffaceous material or ash were also observed. These flows correspond to the lavas on Kruzof Island in the Sitka district to the northwest.

OUTLINE OF GEOLOGIC HISTORY.

The data set forth in the preceding pages are inadequate for the presentation of a complete account of the sequence of events in the Ketchikan and Wrangell districts. In the course of the field work, however, many facts in reference to stratigraphic succession and structure have been obtained, which will be fully used in later reports on this general region. Though the stratigraphy has not been worked out in detail, it does not on the whole appear to be complex except along the boundaries of the Coast Range granitic intrusions, where considerable metamorphism and local disturbances of strata have taken place.

In this province the sedimentary record begins with the deposition of a series of fragmental rocks, now represented by banded quartzite, sandstone, a few beds of conglomerate, and some tuffaceous material. These clastic rocks grade upward into calcareous beds and into limestone containing Silurian fauna. Though the age of the earliest sediments has not been determined, they are believed to be mostly Silurian, as they are succeeded with apparent conformity by limestones of that age. However, since their thickness is estimated at 10,000 feet or more, it is possible that their deposition began in an earlier period. At all events this record shows that sedimentation was probably continuous during early Silurian time, that clastic rocks of great thickness were deposited, and that there was then a gradual deepening of the sea so that several thousand feet of limestone strata were laid down. After the deposition of this Silurian limestone a period of earth movement possibly intervened, during which the rocks were indurated and more or less folded. Of this fact, however, there is no definite proof.

The oldest member of the Devonian is a succession of conglomerate and sandstone beds, composed largely of igneous material, which in most places appear to be less altered than the Silurian limestones and underlying clastic rocks. The pebbles of the conglomerate are embedded in a tuffaceous matrix and were chiefly derived from the older banded quartzite and limestone strata. This series, which is estimated to be 3,000 feet thick, grades upward with ap-

parent conformity into the lower Devonian limestones. These calcareous beds are nearly 2,000 feet thick and their period of deposition probably extended well up into middle Devonian. In other parts of the region the middle Devonian is represented by argillaceous schists and slaty limestones, but the relations between these and the early Devonian limestones are not known. After deposition of the slaty limestones and argillites and apparently conformable with them a limestone of considerable thickness was laid down in upper Devonian time. This later limestone, though highly crystalline and folded in places, does not generally show the intensity of dynamic action which characterizes the older limestones. At the close of the Devonian volcanic activity began along this coastal belt, and lavas were poured out and tuffs laid down to an estimated thickness of about 800 feet. These volcanics were not observed in the Ketchikan and Wrangell districts but are prominent on Chichagof Island to the north, where they overlie and are interstratified with the upper Devonian limestone beds, indicating that their extrusions were submarine. The evidence from adjacent provinces, notably in the Yukon basin, tends to show that this epoch of volcanism was widespread. The so-called Rampart series of the Yukon appears to belong to the same general epoch as the upper Devonian of southeastern Alaska. Volcanic activity apparently ceased toward the end of the Devonian.

The lower Carboniferous period seems to have been inaugurated by the deposition of gray limestone beds 1,500 feet or more in thickness, and, though the relations between these beds and the underlying volcanics were not definitely determined, it is probable that deep-sea conditions continued from upper Devonian into early Carboniferous time. An unconformity between the lower and the upper Carboniferous is suggested by the occurrence of argillites, sandstones, and conglomerates having a thickness of 200 feet or more. On Kuiu Island these underlie conformably 600 feet of clearly exposed upper Carboniferous limestone, which is broadly folded and shows comparatively little metamorphism. Along the mainland the corresponding limestone beds are interstratified with argillites and crystalline schists and are closely folded and highly metamorphosed. Argillites were extensively laid down at the close of the Carboniferous. A period of volcanic activity ensued resembling that at the end of the Devonian, but of much longer duration. The beds of lava and ash ejected from the volcanic vents were contemporaneous with the slate beds, and because of their intimate association with the sediments the volcanics are regarded as submarine extrusives. They are now represented by the altered massive greenstones and greenstone schists, which are widely exposed throughout the region, and together with the interstratified slate beds have a thickness estimated at about 4,000 feet.

The sequence of geologic events during the Mesozoic period is not clearly defined because of the lack of paleontologic and structural evidence and because of the great orogenic changes which took place during this era. During early Mesozoic time the bedded rocks suffered intense metamorphism and recrystallization, resulting in the conversion of the sedimentary strata to schists and slates and in the alteration of the volcanic rocks to amphibole schists and chloritic greenstones. At the same time the beds were highly tilted and intricately folded, the direction of the axes of folding being generally southeast-northwest. These changes are exemplified more clearly in the rock beds flanking the Coast Range than in the sedimentaries composing the outer islands. Though early Mesozoic rocks have not been recognized, it is probable, as suggested by Brooks,[a] that Triassic beds are infolded with these older metamorphosed sediments. The large development of the Triassic deposits to the south in British Columbia points to the same surmise. The only evidence that the Triassic is represented in this region is that a group of fossils found in a piece of limestone float were determined to be Triassic.

During Mesozoic time, the most important event in this district was the intrusion of the great batholiths of the Coast Range. A study of the section across the axial mass of the Coast Range itself shows that the mass is not a simple batholith, but is made up of successive intrusions along the same general line of weakness in the earth's crust. On the outlying islands granitic masses, which are much altered and contain many shearing planes, are invaded by granitic intrusives only slightly altered, which in turn are intruded by pegmatitic dikes and masses. Between these successive intrusions considerable time probably elapsed. The main folding and tilting of the bedded rocks referred to above probably preceded the actual invasion of the granodioritic rocks, as suggested by A. C. Spencer.[b] This is based on the fact that their lines of intrusion are in a broad way parallel to the bedding planes and schistosity of these older rocks, also on the fact that a few inclusions of schist fragments occur within the intrusive massif. In order to control thus effectively the lines of intrusion of the granodiorites, the invaded sedimentaries must have been highly tilted previous to the time of igneous intrusions.

From observations made in southeastern Alaska and elsewhere it is evident that the geologic processes which combined to produce these vast intrusions and structural phenomena acted very slowly and over long periods of time. Though the Coast Range intrusion is generally considered as having occurred at one period, which is undoubtedly true for limited areas, it is probable that in southeastern Alaska at

[a] Brooks, A. H., Ketchikan mining district: Prof. Paper U. S. Geol. Survey No. 1, 1902, pp. 22–28.

[b] Bull. U. S. Geol. Survey No. 287, 1906, p. 19.

least considerable time intervened between the first granite invasion and final solidification of the last intrusive masses. Though it is not possible now to refer these granitic intrusions in this province to a definite geologic horizon evidence from adjacent provinces indicates that they continued at least to late middle Jurassic time. These invasions of igneous material were evidently the cause of the vast amount of metamorphism and deformation of the sedimentary strata along their contacts. It is also probable that the formation of many of the ore deposits occurred just after these igneous invasions, the intrusive containing the material for the ore. The transfer of igneous material to points nearer the earth's surface naturally produced strains in the earth's crust which found relief in cracks and fissures and along lines of brecciation, as well as at the contacts of the intrusives. The lines of weakness thus formed furnished channels of free circulation for mineralizing solutions, which are believed to have been derived for the most part from the igneous masses themselves and to have been given off during the process of solidification.[a]

A period of erosion appears to have followed the intrusion of the Mesozoic granite, and later another epoch of volcanism began. The volcanic rocks of this later epoch are represented by tuffaceous deposits and lavas occupying considerable areas in the southern and western parts of Prince of Wales Island, where they lie on the eroded surface of the granite and are followed by or interstratified with deposits of clastic rock. These rocks may be considered equivalent in a general way to the sediments found north of this province on Admiralty Island, where banded calcareous slates carrying lower Cretaceous fossils occur.[b] The steeply tilted attitude and metamorphosed condition of these volcanics indicate that they were folded after their deposition and induration. The effect of the forces producing these structural phenomena appears not to have been widespread, as it did not modify to any great extent the early Mesozoic folding which preceded the intrusion of the granite.

After the deposition and folding of these Mesozoic strata a long period of quiescence appears to have ensued during which erosion probably was extensive. In late Cretaceous or upper Eocene time sedimentation took place in local basins. These beds including fine conglomerate and shales with some lignite were subsequently tilted and faulted, but this disturbance was apparently local. No evidence of marine life has yet been found in them and it is possible that in this section of Alaska they were fresh-water accumulations. They occur only locally near sea level and in low-lying valleys and basins practically inclosed by mountains of granite and older metamor-

[a] The origin of the ore deposit is more fully discussed in the following pages under the heading of "Ore deposits."

[b] Bull. U. S. Geol. Survey No. 287, 1906, p. 144.

phosed rocks. These beds represent the most recent sedimentary formations of the Wrangell and Ketchikan districts and subsequent to their deposition wide areas of land were flooded by basaltic lavas which poured forth through fissures in enormous volume. These lava flows are flat-lying and on Kuiu Island attain a thickness of over 1,500 feet. They were probably extruded at the close of the Eocene.

A large part of the Tertiary sediments may have been subsequently removed by erosion, for there must have been a long period of quiescence after their deposition and deformation. The next important event in the region was the development of the ice sheet which covered the entire district under consideration. Its retreat left the topography in essentially its present form. After the retreat of the ice some lava sheets were locally erupted.

ORE DEPOSITS.

GENERAL DISTRIBUTION OF MINERALIZATION.

In the foregoing pages the geography and geology of the districts have been described, especially with reference to their bearing on the character and distribution of the ore deposits. As a whole the Ketchikan and Wrangell districts owe their present economic importance mainly to the ores of copper, the occurrence of other minerals being commercially of minor significance. Gold alone is mined at several places, but the copper ores afford a more important source of gold. Deposits of silver-lead ores are being developed in both districts, but the production from such properties has been small.

MINERALIZATION IN THE COAST RANGE INTRUSIVE BELT AND ADJACENT SCHISTS.

Within the mainland belt, which includes the eastern portion of Revillagigedo Island in the Ketchikan district, mineralization is scattered both in the granitic intrusives and the adjacent schists, but mineralized zones, corresponding to those in the Juneau gold belt to the north, are less strongly marked. Quartz veins and metallic impregnations are found only locally, and prospecting has revealed comparatively few valuable ore deposits in the areas covered by these rocks. Explorations have been confined, however, mainly to the shores of the deep narrow fiords, from which the mountains rise abruptly to high altitudes. Steep, forest-covered slopes make prospecting difficult and have restricted the knowledge of the greater portion of the schist belt to the vicinity of salt water. The ore bodies thus far disclosed have been developed near Smeaton Bay in Behm Canal; at Sealevel, on the northeast side of Thorne Arm; and near

the head of Carroll Inlet in the Ketchikan district. For the most part they consist of simple veins in fissures and lode deposits of complex composition. They contain only moderate values in gold. In the Wrangell district the schists and argillites near the Coast Range intrusives are less highly metamorphosed than those to the south; moreover, their northwest trend and northeast dip are more uniform. The structural relations resemble somewhat closely those of the Juneau district to the north, where distinct belts of mineralization have been traced for many miles. In the Wrangell district such a belt has been observed along and near the contact of the Coast Range granodiorite. The Groundhog and Glacier Basin groups of claims are located in this belt, which is characterized by veins rich in argentiferous galena. Prospects similarly situated with respect to the granite have also been located near Thomas Bay in this district.

MINERALIZATION IN THE SLATE-GREENSTONE BELT.

Ore bodies of considerable importance have been developed in the slate-greenstone belt, which borders Tongass Narrows, includes the western portion of Cleveland Peninsula, and extends northward along Duncan Canal. They are largely lode deposits or mineralized bands, within which the greenstone-schist country rock has been sheared and fissured and then permeated by the mineral-bearing solutions. In these mineralized bands or lode deposits the country rock has a bleached appearance and is impregnated with small cubes of pyrite and other sulphide ores. Locally narrow seams of massive sulphide ore are found and native gold is often visible in the vein quartz or as thin films or flakes along the jointing cracks and slipping planes. Besides gold and small values in silver, copper also occurs in limited amounts in some of the deposits of these rocks. The principal lode deposits of this type are in the Goldstream mine on the east side of Gravina Island, the Old Glory mine on Cleveland Peninsula, and the prospects on Portage Mountain at the head of Duncan Canal.

Though quartz veins are prominent throughout the slate-greenstone belt, some of which show particles of native gold, most of them are too small or the gold content is too low to pay for mining. Veins of sufficient size to be mined separately have been located at the Gold Standard and Gold Mountain groups of claims on Cleveland Peninsula, at the Hoadley claims 3 miles north of Ketchikan on Revillagigedo Island, and at several points along the east shore of Gravina Island in the Ketchikan district, and on Woewodski Island in the Wrangell district. Gold is the important metal of these vein deposits.

MINERALIZATION ON PRINCE OF WALES ISLAND AND THE SEAWARD ISLANDS.

On Prince of Wales Island the regularity of the rock structure is locally interrupted by the broad and irregular intrusive areas of granitic rocks, and for this reason the ore bodies are not traceable along definite zones. Mineralization in general is closely related to the intrusive rock masses, and many of the deposits are at the contacts of the intrusives, or in their vicinity.

The copper ores generally favor contact aureoles adjacent to the granodiorite or syenite intrusives. They occur as large lenticular bodies and as veins of nearly massive sulphide ore, composed of pyrite, chalcopyrite, magnetite, and pyrrhotite in a matrix of garnet, quartz, calcite, and other gangue minerals. Such deposits are found in the vicinity of Hetta Inlet and on Kasaan Peninsula. Bodies of copper ore inclosed in a greenstone-schist country rock, both in the form of lenticular masses and as veins, occur at Niblack Anchorage, the head of North Arm, and in Hetta Inlet. Bornite and chalcopyrite occur in small patches disseminated locally in the granitic intrusives and are being explored on the Goodro claims to the northeast of Karta Bay.

On Prince of Wales Island gold occurrences are principally confined to the limestones and phyllites and are being mined in the vicinity of Hollis, on Cholmondeley Sound, and at Dolomi. At these points the gold occurs in veins of quartz and in lodes following lines of brecciation in the limestone. It is commonly present in the native form and is in many places accompanied by considerable amounts of silver and copper. The principal ore minerals are pyrite, galena, sphalerite, and tetrahedrite.

Auriferous veins in the granitic intrusives have been located and partially developed on Granite Mountain to the west of Karta Bay, at several points in the vicinity of Shakan, and at Ratz Harbor in Clarence Straits. These instances emphasize the fact that the granitic areas are not always barren of ore, as is often presumed.

Ores of silver, lead, and zinc have been observed at several localities on Prince of Wales Island, though the only deposit being developed is on the Moonshine claim, in Cholmondeley Sound. At this place the ore occurs in a well-defined vein traversing the limestone and greenstone schist country rock.

On Dall Island, southwest of Prince of Wales Island, auriferous quartz veins and belts of schists impregnated with gold-bearing sulphides have been partially developed at Dakoo Harbor, 2 miles north of Cape Muzon. Deposits of chalcopyrite ore are being investigated near Sea Otto Harbor, on the west side of the island. At Mount Vesta, on the east side, veinlets of tetrahedrite and galena ore occurring in a limestone belt were observed.

On Baker Island, north of Dall Island, quartz veins in a granitic intrusive belt have been prospected to a large extent, but with little success. Chalcopyrite, associated with pyrrhotite, has been discovered at the granitic contact on the north end of Noyes Island, but is yet to be developed.

The deposits on Coronation Island, which have incited considerable mining interest the last few years, are replacement deposits of galena ore in limestone. They are irregular in occurrence and not of great extent. Granite intrusives were observed in the vicinity and the deposits are probably genetically related to them.

On Kuiu Island, the second largest island in the Wrangell district, metalliferous deposits have not been found. This may be attributed to the absence of intrusive rocks on the island, only one small area, at Washington Harbor, having been observed.

PRINCIPAL CHARACTERISTICS OF ORE DEPOSITS.

GENERAL STATEMENT.

In the Ketchikan and Wrangell districts four general types of ore deposits have been recognized, vein deposits, breccia veins, lode deposits, and contact deposits, the latter being of greatest importance. Deposits of a character intermediate between these general classes also occur and their peculiar features are discussed in the detailed descriptions. The distinctive characteristics of the different minerals contained in the ore deposits are considered separately under "Character of minerals." Placer deposits, from which the greatest percentage of gold is derived, have not been developed in this section of Alaska.

VEIN DEPOSITS.

The term "vein deposit" is here applied to any mineral mass or aggregate occupying a fissure or fracture in the rocks. In this region they are usually made up of auriferous quartz and calcite, with a small percentage of metallic sulphides, but veins of nearly massive sulphide ore rich in copper, or in some instances containing lead and silver, are also present. The vein deposits occur in practically all of the older rocks of the district, including the intrusives, but are rarely found in late Mesozoic rocks and have never been observed in the Tertiary sedimentaries or eruptives. These fissures were primarily due to strains in the earth's crust, which may be ascribed to earth movements at present but imperfectly understood. These cavities were natural conduits for the circulation of mineralizing solutions, which contained large amounts of quartz, lime carbonate, metallic sulphides, and other minerals. The solutions were probably heated, and as they ascended through the fissures the conditions of solution changed and the contained minerals were deposited, thus

forming the veins. The origin of the mineral solutions is speculative, but the intrusive rock masses are probably the source, because there is no evidence of mineral deposits formed previous to their invasion, or in the subsequent rock formations.

In their form and mode of occurrence the veins exhibit much irregularity. Those that traverse the foliation of the schistose country rock obliquely are in many places more strongly developed and better defined than those that parallel the rock structure. They vary in width from a few inches to 10 feet or more, and are usually less than a thousand feet in horizontal extent, though a few veins are several thousand feet long. It is notable that while portions of a vein contain high values, other portions are practically worthless, and that the richer portions or pay shoots usually follow certain lines pitching at variance with the dip of the vein. Instances of such pay shoots were noted at the Sea Level mine on Revillagigedo Island, at the Gold Standard mine on Cleveland Peninsula, at the Crackerjack mine near Hollis, and at other mines.

Few of the veins show signs of surface oxidation of the minerals. Their croppings expose the unaltered sulphide ore, usually pyrite, and only rarely has this been oxidized to limonite so as to form an iron cap or gossan. Secondary enrichment is entirely absent in the fissure-vein deposits. If such enrichment existed previous to the glacial epoch it was scoured away by the moving ice streams. More recent weathering has affected the rocks to only a slight depth.

Most of the veins dip steeply or stand nearly vertical. At the time the veins were formed the present outcrops were probably several thousand feet below the earth's surface, and since they were formed from material derived from still greater depths, it may be surmised that similar veins will extend to considerable depths, though individual veins may be cut off by faults or by a gradual wedging of the inclosing fissure.

The walls or country rocks are everywhere considerably altered and in some places consist entirely of metamorphic minerals, including epidote, chlorite, mica, quartz, and calcite. Metallic minerals in many places impregnate the vein walls, and in certain localities the rock adjacent to the vein constitutes a part of the ore.

BRECCIA VEINS.

The term breccia veins is here used to designate masses of breccia rock occurring in more or less tabular form which have been infiltrated and impregnated by quartz and metallic sulphides. Limestones and schists are the usual inclosing rocks, and in these the veins are either parallel to the bedding planes or crosscut them at narrow angles.

Deposits of this sort are found at Dolomi and in Cholmondeley Sound, on the east side of Prince of Wales Island. At Dolomi the Valparaiso, Paul, and Jessie veins are typical of these brecciated vein deposits, and in Cholmondeley Sound the Gladstone and Equator veins are most typical. These veins range from 2 to 10 feet in width and many of them are traceable for 1,000 feet or more. Quartz forms the cementing material between the brecciated limestone fragments, and to some extent has replaced the rock itself. Sulphide minerals carrying the gold values are contained in the limestone fragments as well as in the quartz, and to a less extent in the unbrecciated rock adjacent to the vein. Because of this replacement of the inclosing rock and the lack of definite walls, it is sometimes difficult to determine the lateral limits of the ore, and assays of the rock are necessary. In some places, as was noted in the Valparaiso vein, the walls are defined by narrow veins of massive quartz 1 to 2 feet in width, with 4 to 6 feet of brecciated ore between. These quartz veins were separated from the intervening breccia by thin seams of gouge matter, indicating movement of the walls subsequent to their deposition. Gold is the principal metal contained in these deposits and is largely free-milling. Pyrite, chalcopyrite, tetrahedrite, galena, sphalerite, and arsenopyrite occur in varying amounts in most of these veins. Surface weathering has oxidized the surface outcrops, in places to a depth of several feet, forming a gossan composed of limonite, hematite, malachite, azurite, and other minerals. In these breccia veins the richer ore generally occurs in the form of shoots, pitching at an angle to the dip of the vein.

LODE DEPOSITS.

The type of mineral deposit here defined as "lode" consists of bands of schistose rock intersected by veinlets of quartz and calcite and impregnated with metallic sulphides. These lodes may vary from 5 to 50 feet in width, and are usually of great persistence both in length and depth. They invariably follow the structure of the inclosing rock, and the ore is of more uniform grade in them than in the fissure veins. Gold, which is the principal metal in them, is confined largely to the quartz and calcite veinlets. The lode deposits are not so important in this region as in the Juneau district[a] to the north. This type of mineralization is most prominent in the slate-greenstone belt, and ore bodies of this sort are being mined at the Keystone claim on Cleveland Peninsula and at the Goldstream mine on Gravina Island. At these localities the inclosing rock is a greenstone schist, which within the lodes is changed to a soft grayish or pale-greenish rock, consisting chiefly of carbonates of lime and mag-

[a] Spencer, A. C., The Juneau gold belt: Bull. U. S. Geol. Survey No. 287, 1906.

nesia, with sericite and some chlorite. The metallic sulphides, essentially pyrite with some chalcopyrite, are finely disseminated throughout the rock and amount to about 3 to 6 per cent. The lateral limits of the deposits are not sharply defined, and in the altered country rock the mineralized portion gradually changes to the unmineralized schist.

The origin of the lode deposits is believed to have been similar to that of the fissure veins. Mineral solutions of magmatic origin permeated and altered the schists, and deposited in them the sulphide minerals. The rocks were then fractured and veinlets or stringers of quartz and calcite were deposited. Subsequent movements have caused slipping and shearing planes within the lodes, but large transverse faults were not observed.

Surface waters and other surface agencies have had practically no effect upon this type of deposit since the glacial epoch, and secondary enrichment does not occur.

CONTACT-METAMORPHIC DEPOSITS.

Among the most valuable mineral deposits in the region are the contact metamorphic deposits, which are largely developed on Prince of Wales Island. This term is here restricted to those mineral veins or ore masses which have been formed by contact metamorphic agencies and which carry the minerals characteristic of such action. A contact metamorphic deposit must, therefore, be in the vicinity of an intrusive rock but not necessarily at its contact. Such deposits occur mostly in limestone or calcareous rocks usually within 1,000 feet of the intrusive rock masses. They are believed to be of magmatic origin and to have been formed by gaseous and aqueous emanations given off from the igneous intrusive during cooling and solidification. As lime carbonate is a ready precipitant of these mineral solutions, the largest ore masses are usually formed at points where limestone is the intruded rock.

The characteristic minerals associated with the contact metamorphic deposits are chalcopyrite, pyrrhotite, pyrite, and magnetite in a gangue of garnet, epidote, calcite, quartz, amphibole, wollastonite, and several rare minerals. These minerals are admittedly the typical products of contact metamorphism, and their nature and intergrowth show that they result from the action of hot solutions. Mineralogically they differ from the ores of other deposits, especially in the contemporaneous formation of oxides and sulphides, principally of iron, and in their association with the various lime-silicate minerals enumerated above. Within these contact aureoles the mineral deposits assume many forms. They occur not only as veins

filling fissures a few hundred feet in length, crosscutting the intruded rock beds, but also in the intrusive mass itself, and as banded replacement deposits, where mineral deposition has taken place along the bedding planes of a quartzite country rock and the intervening bands have been more or less completely replaced by vein material. Of greatest importance, however, are the masses composed largely of metallic sulphides and magnetite. These ore bodies are irregular masses ranging from 20 to 200 feet in lateral dimensions and from 100 to 300 feet in depth. Such deposits are largely developed at Copper Mountain and on Kasaan Peninsula, both localities on Prince of Wales Island, and their characteristics are discussed under the detailed descriptions.

CHARACTER OF ORES.

The important ores of the Ketchikan and Wrangell districts are not of great variety and their association is not unlike that of the other lode-mining areas in Alaska. Most of the ores are primary sulphides; the only recognized ores of secondary origin which occur in commercial amounts are the copper carbonates at Copper Mountain.

COPPER ORES.

The principal copper mines in the region are developing deposits of a low-grade copper-iron sulphide ore which can be profitably exploited only by extreme economy in extraction. In certain instances the accessory gold content of $1 and $2 is depended on to raise the total value of the ore above the commercial limit. The copper ores generally contain high percentages of iron and lime and are classed as "base ores" by the smelters. Therefore, to acomplish their reduction, it is necessary to mix them with siliceous or quartz ores. The lack of available siliceous ore has been a serious handicap to the smelters of the district. Increasing the value of the copper ores by concentration alone would in most cases be of little advantage, both because of the high percentage of iron minerals and because only the lighter siliceous minerals would be separated, which are necessary as a flux. In some instances, however, a grinding and treatment of the ores in a magnetic separator might be done to advantage.

These facts are clearly brought out in the following table, which shows the composition of the gangue content of the ores from the principal mines, as determined by smelter assays.

Smelter assays of ores from copper mines in the Ketchikan district.[a]

Name of mine.	SiO_2 (silica).	Fe (iron).	CaO (lime).	S (sulphur).	Al_2O_3 (alumina).	MgO (magnesia).	Zn (zinc).
Mamie mine:							
Siliceous ore	30.6	17.5	10.4	5.9	17.2	----------	----------
Base ore	10.6	47.8	2.7	6.3	7.7	----------	----------
Stevenstown mine	16.4	34.1	7.6	6.9	11.7	----------	----------
Mount Andrew mine	15.2	42.8	.4	4.3	----------	----------	----------
Karta Bay mine	16.5	35.6	6.8	6.2	----------	----------	----------
	19.6	28.3	7.0	8.0	----------	----------	----------
Niblack mine	27.2	24.6	1.0	22.8	5.6	1.2	1.0
	41.8	18.4	1.7	14.8	7.8	3.9	1.9
Omar Khayyam mine	12.0	37.0	1.2	41.0	4.0	Tr.	----------
Cymru mine	74.2	8.6	1.8	7.4	1.1	----------	----------
Copper Mountain mine, surface ore	37.7	17.3	12.1	.3	12.0	----------	----------
Copper City mine	12.4	27.2	1.6	22.6	4.36	----------	8.4

[a] The above assays were kindly furnished to the writers by the Alaska Smelting and Refining Company and by the Tacoma Smelter.

The preceding analyses, though incomplete, show the relative basic and siliceous content of the ores. The portion of the analyses not given represents the moisture (H_2O), the carbon dioxide (CO_2), the undetermined elements, including the alkalies contained in the ores, and also their content of precious metals.

GOLD ORES.

Although gold is distributed through all the older rock formations within the region, the localities which show sufficient concentration of auriferous minerals to make workable ore bodies are relatively few, and the values found are usually low. The low cost of transportation and the available water power, however, make it possible at many places to extract the ores at a profit.

The gold mines operating in the Ketchikan and Wrangell districts are producing a free-milling ore, i. e., an ore from which the greater percentage of the gold content may be extracted by amalgamation. Some of these ores have been shipped to the smelter, but unless the charges for reduction are exceptionally low it would appear that the ores should be concentrated and these concentrates alone shipped to the smelter. The amount of concentrates derived from the gold ores seldom exceed 5 per cent.

ORE MINERALS.

NATIVE MINERALS.

Gold.—Gold, the only native metal found in commercial quantities, occurs in vein and lode deposits. Small quantities of gold are also present in the alluvium, notably that of Stikine and Unuk rivers. Visible particles of gold are scattered through the vein quartz and associated with pyrite to some extent in the adjacent country rock at Crackerjack and Puyallup mines near Hollis, at the Gold Standard

mine on Cleveland Peninsula, at the Hoadley group just north of Ketchikan, at Sealevel in Thorne Arm, and at other points. Gold is also found in small particles associated with galena and sphalerite in narrow seams and in the form of thin flakes along jointing and slipping planes in the lode deposits at the Gold Stream mine and other localities. In the breccia deposits at Dolomi many of the veins show native gold associated with secondary minerals, such as limonite, malachite, and azurite, apparently derived from original sulphide ores by weathering. In many of the deposits, however, the gold is contained largely in sulphide minerals, and its association with the sulphide, usually pyrite, is so intimate that fine milling and amalgamation fail to extract the metal. Many of the sulphide concentrates from these ores contain from 5 to 10 ounces of gold.

Copper.—Metallic copper was observed at the surface croppings of the copper deposits at the head of Duncan Canal, at Copper Mountain, at Skowl Arm, at Cholmondeley Sound, and on Kasaan Peninsula. In this relatively rare mode of occurrence the copper is in thin sheets along clay seams or slipping planes and has been derived from the alteration of chalcopyrite.

SULPHIDES, TELLURIDES, ARSENIDES, ETC.

Chalcopyrite.—Chalcopyrite, which forms the bulk of the copper ores of the districts in all the various types of deposits, is composed of the sulphides of copper and iron and when pure contains 34.5 per cent of copper. It occurs associated with pyrite, pyrrhotite, and magnetite in a gouge composed of garnet, epidote, quartz, calcite, and amphibole minerals and in quartz veins with galena and zinc blende. Chalcopyrite associated with biotite and amphibole has also been found finely disseminated in the intrusive rocks, but in these cases it was evidently not an original mineral of the rock.

As platinum has been found in association with chalcopyrite ores elsewhere, it seemed desirable to test these ores for this metal as well as for their gold content. Large samples of chalcopyrite ore as nearly pure as possible were taken from three mines and analyzed by Mr. Locke with the following results:

Analyses of chalcopyrite ores.

[Analyst, Locke.]

Sample number.	Locality.	Platinum.	Gold.
		Ounce per ton.	*Ounce per ton.*
1	Mamie mine, Ketchikan district	None.	0.04
2	Stevenstown mine, Ketchikan district	None.	.06
3	Mount Andrew mine, Ketchikan district	None.	.08

These analyses did not reveal a perceptible amount of platinum in the chalcopyrite, yet showed a gold value of from $0.80 to $1.60 per ton.

Bornite.—Bornite is also a copper-iron sulphide containing 55.5 per cent copper, and may be easily recognized by its iridescent or copper-red color. It has been found only at the Goodro prospects on Prince of Wales Island, where it is distributed in small particles and masses associated with chalcopyrite, secondary biotite, and epidote near the contact of a basic dioritic intrusive.

Pyrite.—The most common metallic sulphide known in the region is pyrite. It is present in the form of small but perfect cubes throughout the metamorphic schists, slates, and greenstones, and is finely disseminated in the igneous rocks. Alone it is of little commercial value, but where associated with gold it may form a valuable ore. Auriferous pyrite, which constitutes the larger percentage of the ore concentrates, is supposed to be a mechanical combination by which the gold is distributed throughout the pyrite in minute films and particles, which, however, can not be separated by the usual method of amalgamation. Pyrite in a pure state contains 53.4 per cent of sulphur and is the raw material for the manufacture of sulphuric acid. At one locality, Skowl Arm, where large bodies of this sulphide occur, the advisability of mining pyrite for its sulphur content, which amounts to about 40 per cent, is being considered.

Pyrrhotite.—The mode of occurrence of pyrrhotite is similar to that of pyrite, but it is not so broadly distributed. It is a sulphide of iron containing less sulphur than pyrite and may be distinguished by its darker bronzelike color and its magnetic properties. Pyrrhotite is largely developed in all of the copper contact metamorphic deposits and occurs finely disseminated in the intrusives near their contacts.

Some pyrrhotite ores elsewhere contain nickel in sufficient amount to form a nickel ore. For this reason and because some masses of this mineral were reported to contain large amounts of cobalt, samples of nearly pure pyrrhotite were taken from three localities and submitted for the determination of their nickel, cobalt, platinum, and gold content, with the following results:

Analyses of pyrrhotite ores.

[Analyst, George Steiger, U. S. Geological Survey.]

Sample number.	Locality.	Nickel.	Cobalt.	Platinum.	Gold.
		Per cent.		*Ounces per ton.*	*Ounces per ton.*
4	Brown and Metz claim, north end Noyes Island, Ketchikan district.	0.1 to 0.2	Trace.	None.	None.
5	Sultana claim, north side Hetta Inlet, Ketchikan district.	.1 to .2	Trace.	None.	None.
6	Iron Crown claim, Copper Mountain, Ketchikan district.	.1 to .2	Trace.	None.	None.

Galena.—The lead sulphide, galena, containing 86 per cent of lead and usually a small amount of silver, has been found at several localities. It occurs with sphalerite, pyrite, and tetrahedrite, and also with silver and gold in small amounts. Galena is the principal ore of the Moonshine prospect on Cholmondeley Sound, and at the Groundhog and Glacier basin prospects on the mainland east of Wrangell. At the Moonshine group of claims it occurs both in a coarse crystalline state and in a fine compact state, the latter being called "steel galena." To determine the relative amounts of silver contained in the two varieties the mine owners took samples which were assayed with the following results:[a]

Analyses of galena.

	Silver.	Lead.
	Ounces per ton.	*Per cent.*
Fine-grained compact galena ore	17.6	66.6
Coarse-grained galena ore	21.2	78.9

The lead-silver ratio is practically the same in both cases. Galena also occurs in variable amounts, usually small, associated with the gold ores, at Dolomi, on Annette and Gravina islands, on Cleveland Peninsula, and at Thomas Bay. It is rarely present in the copper contact deposits.

Sphalerite.—The mineral sphalerite, commonly known as zinc blende or black jack, occurs under practically the same conditions as galena, with which it is usually associated, but at no place has it been found in sufficient quantity to make a zinc ore. Besides the localities mentioned where galena occurs it has been found in considerable amounts at some prospects on Beaver Mountain in Hetta Inlet and is present in the copper ores at Niblack and Copper City.

Tetrahedrite.—Gray copper ore, as tetrahedrite is usually termed, is a copper-antimony sulphide which may be distinguished from sphalerite by its lack of cleavage and its dark brown to black streak. It has been found at Dolomi, on Annette Island and on Kasaan Peninsula associated with chalcopyrite, pyrite, galena, and sphalerite in the quartz veins inclosed in limestone. Tetrahedrite, though a copper ore, was not observed in the copper deposits, and it is important only because of the gold and silver which usually accompany it.

Tetradymite.—A telluride of bismuth, called tetradymite, occurs with the gold ores at the Hoadley claims north of Ketchikan and at the mines on Cleveland Peninsula. It is a relatively rare mineral of a steel-gray color with a perfect basal cleavage and usually a

[a] These analyses were kindly furnished to the writer by Mr. Catlin, of Ketchikan.

prismatic form. It has been confused by the miners with petzite, the gold-silver telluride, a mineral which has not been observed in the region, though it may be present in some of the gold ores.

Arsenopyrite.—A sulpharsenide of iron, called arsenopyrite, was observed in the quartz veins at several localities in small and unimportant amounts. It may be distinguished from pyrite by its silver-white color. At the prospects in Thomas Bay it is found in considerable quantities containing gold values, and is associated with pyrite, galena, and some sphalerite.

Molybdenite.—Flakes of molybdenite, molybdenum sulphide, are found in some of the quartz veinlets occurring in the metamorphic schists and the intrusives of the mainland. It also occurs in small amounts in some of the contact metamorphic deposits on Prince of Wales Island. A small vein showing a considerable amount of this sulphide was observed in the schists on the north end of Noyes Island. Molybdenite is one of the rare minerals of this region, and so far as known does not occur in commercial amounts. It is a soft, flaky mineral with metallic luster resembling graphite, but having a bluer tinge.

OXIDES, CARBONATES, AND SILICATES.

Magnetite.—The principal occurrence of the magnetic oxide of iron is in association with the copper deposits. At the copper mines in Kasaan Peninsula magnetite forms about half of the ore mass and occurs in large amounts in some of the deposits in the vicinity of Hetta Inlet. Minute grains and small octahedral crystals of magnetite occur scattered through the ferromagnesian silicates and less plentifully through the groundmass as an accessory constituent of the dioritic intrusives and the greenstones. Magnetite was not observed in the quartz veins, though it is present in many of the pegmatite dikes. At several places on Prince of Wales Island magnetite occurs in masses sufficiently high in grade to make an iron ore, though no attempt has been made to mine it as such. The presence of chalcopyrite in these magnetite masses makes them important as copper-bearing deposits, though in many instances the content of the metal is not sufficient to insure profitable mining. The mode of occurrence of the magnetite, associated in masses with chalcopyrite and pyrite, shows that it was deposited under similar conditions, and that it is a primary ore mineral, as the latter evidently are. In the intrusives, however, it is apparently an original constituent of the rock.

Hematite.—Hematite, also an oxide of iron, occurs in the form of specularite or micaceous hematite in the contact copper deposits, though only in minute scattered grains. At the Niblack mine it forms small masses accompanied by quartz in the ore bodies. It was not observed associated with the auriferous ores.

Limonite.—The hydrous iron oxide called limonite is an alteration product of iron minerals, most commonly of pyrite, and is found at many places, but nowhere in quantity. It occurs with the copper-carbonate ores on Copper Mountain and forms a shallow capping on many of the pyritic ore deposits.

Malachite.—The green carbonate of copper called malachite is usually found in small amounts at the croppings of the copper deposits where limestone forms the inclosing rock. Its principal occurrence is on Copper Mountain, where surface alteration has been extensive and formed small masses of this carbonate ore in the garnetiferous and limestone gangue. The mode of occurrence is mostly in narrow seams or veinlets and as an incrustation or coating on the sulphide ores. Malachite is associated with limonite, chrysocolla, and small amounts of azurite. Its high copper content and the facility with which it may be reduced make it a very valuable ore.

Azurite.—Azurite, like malachite, is a carbonate of copper, but is distinguished by its deep-blue color. Only small amounts of this ore were observed, and it was always in association with malachite as a surficial alteration product of the sulphide copper ores.

Chrysocolla.—The hydrous silicate of copper, called chrysocolla, like malachite and azurite, has been found in quantity only at the Copper Mountain mine, where it is apparently confined to the surface workings and is of only minor importance as an ore.

Quartz.—Quartz is the most common and most important gangue mineral in both the fissure and the lode deposits. It usually occurs as massive quartz and rarely in the form of crystals. At Dolomi in the veins along lines of brecciation in the limestone it forms the cementing material and has replaced to a large extent the surrounded fragments of the limestone. At Niblack in the copper deposits it is associated with small amounts of hematite and forms what is termed "jasper ore." In the contact metamorphic deposits it is present in only small amounts, generally crystallized and associated with epidote and garnet. Many of the crystals are doubly terminated and from 1 to 10 centimeters in length, many of them being twinned. They have formed subsequent to the crystallization of the epidote and garnet and are superimposed on them.

Calcite.—Calcium carbonate, commonly known as carbonate of lime, has the most widespread occurrence of any gangue mineral except quartz. It is readily recognized by its perfect cleavage and its softness. Calcite is particularly prominent in the contact metamorphic deposits and is associated with the galena ores. Where it was observed occurring with garnet and epidote it was invariably of later formation.

Garnet.—In the Ketchikan district garnet forms the principal gangue mineral of the contact-metamorphic deposits and is confined

for the most part to the altered limestones near the intrusive contacts. Though it commonly occurs in massive form, it also appears in crystal aggregates usually of dodecahedral form embedded in the altered limestone. The separate crystals in cross section show a concentric structure resembling banded agate, being made up of green and red bands, which probably represent a slight change in composition during the growth of the crystals. In size the crystals range from 1 to 5 centimeters in diameter, the faces showing a subadamantine luster, though in mass the garnet has the usual luster. To determine the variety of this garnet rock a sample was submitted for analysis, and the results, which were determined by W. T. Schaller, of the United States Geological Survey, are compared in the following table with garnet rock from other localities:

Analyses of garnet occurring in contact metamorphic deposits.

[Analysts: W. T. Schaller, 1; George Steiger, 2–4.]

	1.	2.	3.	4.	5.	6.
SiO_2	35.18	36.26	37.79	37.15	35.5	40.0
Al_2O_3	5.15	.78	11.97	6.98		22.7
Fe_2O_3	25.05	32.43	15.77	19.40	31.5	
FeO	.40	.32	1.31			
MgO	.09	None.	.37			
CaO	33.36	29.67	32.57	32.44	33.0	37.3
H_2O	.42	.57	.09			
TiO_2	None.	None.				
$CaCO_3$		None.		4.20		
P_2O_5		.06				
MnO		.27	.31			
	99.65	100.36	100.18	100.60	100.0	100.0

1. Garnet rock, Jumbo mine, Prince of Wales Island.
2. Garnet, Morenci, Ariz., Prof. Paper U. S. Geol. Survey No. 43, p. 134.
3. Massive brown garnet, White Knob, Idaho: Economic Geology, vol. 2, No. 1, p. 7.
4. Garnet, San Jose, Mexico: Trans. Am. Inst. Min. Eng., vol. 36, p. 92.
5. Typical composition of andradite.
6. Typical composition of grossularite.

From the above analyses it is evident that the greater per cent of the garnet associated with the contact-metamorphic deposits is andradite and not grossularite, as has in many instances been supposed.

The garnet masses are confined principally to the intrusive contacts with a limestone of nearly pure calcium carbonate, thus suggesting that a vast amount of foreign material must have been brought in along the intrusive contacts to have produced the garnet masses. Where the intrusives invade a quartzite country rock, the garnet forms bands interstratifying the siliceous beds, and many of these mineral bands extend thousands of feet from the contacts. At Copper Mountain this mineral forms a massive belt 20 to 50 feet wide between the intrusive diorite and the limestone country rock, and occurs in veins crosscutting the limestone beds and penetrating the intrusive rock. Included in the garnet masses are crystallized particles and small masses of chalcopyrite, magnetite, pyrrhotite, and

rarely pyrite, all of which, combined as they are, constitute the copper ore.

The almandite variety of garnet occurs in great abundance in the mica and chlorite schist near the mouth of the Stikine River. The crystals are from 1 to 4 centimeters in diameter, usually of dodecahedral form, with trapezohedral truncations. Though abundant, this mineral has not been extensively cut as a gem stone on account of its being too opaque and because of numerous fractures or flaws in the crystals.

Epidote.—A calcium-iron-aluminum silicate, called epidote, occurs largely as an alteration product in the igneous rocks and as a gangue mineral in the contact-metamorphic deposits. As a mineral due to contact metamorphism it forms many large crystals associated with garnet quartz and calcite. Specimens of this mineral from the Green Monster copper claims were sent to the Harvard mineralogical laboratory by Mr. W. C. Hart and have been described by Dr. Charles Palache.[a]

Wollastonite.—The metasilicate of calcium, wollastonite, was found forming radiating crystal clusters in the limestone and quartzites a short distance from but not at the intrusive contact. It belongs with the contact-metamorphic minerals of the region, but its occurrence away from the contact suggests that the conditions necessary for its formation were not so intense as those required to produce the garnet and epidote which occur at the contacts.

Scapolite.—Like wollastonite, scapolite occurs in the vicinity of the ore deposits and is a calcium-aluminum silicate containing soda and chlorine. It occurs in prismatic crystals an inch or two in length with rough, uneven faces and is from white to gray in color. It was found only in the vicinity of the Copper Mountain deposits and is not of common occurrence.

Amphibole.—The hornblende variety of amphibole, a calcium-magnesium-iron silicate, is a prominent gangue mineral in some of the contact-metamorphic deposits. At the Stevenstown mine it was observed to form radiating crystal clusters in the inclosing altered schists and was intimately associated with garnet and chalcopyrite. It is also present in the ore deposits at the Mount Andrew and Mamie mines. The tremolite variety, calcium-magnesium silicate, occurs as a metamorphic mineral in some of the limestone beds, notably in the Ham Island marble deposits in the Wrangell district.

Feldspar.—The presence of feldspar in small amounts was noted in several of the vein deposits, more especially in those occurring in the band of crystalline schists, and is of interest because of its probable relation to the granitic intrusives. The variety is mainly that

[a] Proc. Am. Acad. Arts Sci., vol. 37, No. 19, March, 1902, pp. 531–535.

of albite, which occurs in the quartz veins on the Lon de Van claims at the head of George Inlet, at the Birdseye claim to the south of Ketchikan, and at other localities. At the Goodro prospects near Karta Bay albite is found as a vein mineral in the copper deposits associated with secondary biotite and epidote.

Biotite.—Flakes of biotite, commonly termed black mica, were noted rarely in some of the vein deposits. At the Lon de Van prospect mentioned above it is associated with secondary albite and at the Goodro prospects it is a prominent mineral constituent of the copper ores. Its presence in these deposits suggests that conditions of moderately high temperature existed during the ore deposition.

Clinochlore.—Clinochlore, a soft bluish-green micaceous mineral, was observed in considerable amounts occupying small druses and finely disseminated in some of the copper-bearing magnetite deposits on Kasaan Peninsula.

DETAILED DESCRIPTIONS OF MINES AND PROSPECTS.

GENERAL STATEMENT.

A great many prospects and mine workings of moderate extent are located in the Ketchikan district, but the developed and producing mines are few. During the few months devoted to field work in this region nearly 200 localities were examined, including all of the important mines and prospects. In the following descriptions the properties are grouped first according to their chief metal content and then taken up in geographic order. Copper is and probably will be the principal metal product of the district and is therefore considered first, followed by gold and the less important metals. The geology of the region as a whole, the relations of the ore deposits, and the mode of occurrence of the minerals have been discussed in the foregoing pages, and while consulting the following detailed descriptions these general descriptions should be kept in mind. In the following pages one of the principal typical deposits of a locality is generally selected and described in considerable detail, and the other deposits are next discussed according to their importance and the degree in which they vary from the type deposit. At the close of these descriptions the building stones and the mineral and thermal springs are discussed briefly.

COPPER MINES.

GENERAL STATEMENT.

Copper does not occur uniformly throughout the districts. Irregular lenses or masses of the ore are present in the altered greenstone schists at Niblack; in the vicinity of Copper Mountain and on Kasaan Peninsula they are found at the contact of granitic intrusives with

limestone and siliceous schists, and veins of nearly massive sulphide ore occur in a belt of slate-greenstone schist along the shores of Hetta Inlet and at the head of North Arm. In a general way these ore bodies are so irregular that the rule to observe in exploitation is to follow the ore and not drive long crosscut tunnels with the expectation of undercutting the deposit in depth. The bulk of the copper ore is chalcopyrite and cupriferous pyrite, accompanied by magnetite, pyrrhotite, and other sulphide minerals. With one exception, carbonate and oxide ores are practically absent, and the zone of secondary concentration or surface enrichment, prominent in most copper deposits, is wanting or is too small in extent to be important. In general it may be stated that where a sulphide ore is being mined in these districts the values in the ore will not decrease rapidly with increasing depth.

HETTA INLET.

GENERAL DESCRIPTION.

All of the most important discoveries on the west coast of Prince of Wales Island are contiguous to Hetta Inlet, a deep embayment which is connected with the Pacific Ocean through Cordova Bay (see Pl. I). The increasing importance of this area led to the survey of the waterways from the head of Hetta Inlet to the Pacific Ocean during the early part of 1905 by the Coast and Geodetic Survey. With the aid of the chart of this section ocean-going steamers may approach Coppermount and Sulzer with safety.

The head of Hetta Inlet is separated from the west arm of Cholmondeley Sound by a low divide 4 miles across and less than 200 feet high. The Government has built a roadway between the two waterways which permits the shipment of light freight and increases the mail facilities over this relatively short route from Ketchikan to Sulzer and Coppermount. Heavy freight and supplies are delivered by vessels from Puget Sound, which occasionally call at the mining camps along the inlet, and by small steamers from Ketchikan, a distance of 100 miles by water.

The shores of Hetta Inlet, like other parts of the coast, rise precipitously from the water's edge, and the main channel and the harbors are deep. The steep mountains terminate in peaks from 2,500 to 3,800 feet in elevation, many being less than than a mile from tide water. A luxuriant growth of timber and vegetation extends to an altitude of 2,000 to 2,500 feet, and above this the mountains are bare, permitting broad views of the surrounding region. Many inland lakes are included in the area, and their outflowing streams furnish abundant water power the year around. This advantage and the accessible supply of timber are exceptionally favorable for mining.

GEOLOGY.

The accompanying sketch map presents the geologic relations as well as the positions of the mines (Pl. IX). An intrusive stock or boss of granodiorite 8 miles wide occupies the central part of the field and is surrounded by irregular areas of limestone and quartzite. The geologic age of these bedded rocks is Paleozoic. The determination is based wholly on their lithologic and structural features, as no fossil evidence was obtained. The limestone has been so completely metamorphosed to coarsely crystalline marble that its bedding planes are no longer apparent. The quartzites, which have a schistose and wrinkled structure, overlie the limestone and are in turn overlain by a wide belt of greenstone schists, which border the shores of Hetta Inlet. The general strike is N. 15° to 45° W., and the dip is steep to the west, though this has been interrupted in the vicinity of the intrusive granite boss where the stratified rock beds are usually parallel to its contact. Small areas or patches of limestone occur within the granodiorite area where erosion was not sufficient to remove them. The coarsely crystalline character of the intrusive and the alteration of the limestone at points distant from the contact indicate that these rocks were deeply buried at the time of metamorphism and are a measure of the extent of subsequent erosion.

After the erosion of the granodiorite and after the deposition of the ore bodies, dikes, usually narrow, of diabase and diorite-porphyrite were injected. These dikes have no bearing upon the vein deposits except at those places where they crosscut them along lines of fracture, as at the Copper City and Corbin mines.

ORE DEPOSITS.

Distribution.—The principal ore bodies in Hetta Inlet are on the Copper Mountain, Jumbo, Houghton, and Green Monster groups of claims, and are contact metamorphic deposits, confined principally to the aureole of the granodiorite in either limestone or quartzite. The deposits at the Corbin and Copper City mines are vein deposits of massive sulphide ore in the outlying greenstone schists which border the shore of Hetta Inlet.

Effects of contact metamorphism.—The intrusion of the granodiorite batholith appears to have affected an alteration of the adjacent sediments for only a few thousand feet from the contact. Nearer the contact the influence of this intrusive on the stratified rocks is evident only in the quartzite or schistose beds by the development of wollastonite and some garnet and epidote, while the crystalline limestone strata are apparently unaltered. These facts go to show that regional metamorphism previous to the granodiorite intrusion was apparently so intense as to render the rocks little susceptible to further changes.

The changes within the contact aureole due to the indirect effect of the intrusive mass or hydrothermal metamorphism were caused by the vapors and liquid solutions emanating from the igneous magma during the period of its solidification. In the present instance this action has extended much farther than the direct contact metamorphism and has produced wide deposits and veins of garnet and epidote in which the ores occur. The mineral-bearing solutions given off from the unsolidified portions of the igneous masses penetrated the adjacent limestone and quartzite beds, mainly along the granodiorite contact, dissolving channels into the limestone, though often taking advantage of preexisting fissures in both the limestone and granodiorite. During their ascent the thermic and other conditions of the aqueous solutions changed and their mineral contents were precipitated by the limestone and meteoric waters and gradually filled the channels and fissures. The contact metamorphic deposits thus formed are composed essentially of a massive garnet-epidote rock, varying from a reddish to a greenish color, in which grains of chalcopyrite, pyrrhotite, and magnetite are disseminated. In places the rock has a decided granular texture, both the garnet and the epidote having their crystalline forms, and in this the sulphide ore is usually found in small masses accompanied by calcite and quartzite. The width of the contact metamorphic deposits ranges from 25 to 250 feet and the inclosing walls are sharply limited where formed of limestone, but the altered quartzite boundaries were less well defined. Smaller bodies of this vein material are found in fissures branching from the contact both into the limestone and into the granodiorite, the lateral extent of these being usually less than 1,000 feet. A description of both the ore and the gangue minerals found in these deposits is contained in this report under the heading "Ore minerals" (p. 85).

COPPER MOUNTAIN GROUP.

General description.—The Copper Mountain group of claims of the Alaska Copper Company stretches northward from tide water at Copper Harbor across the crest line of a ridge which forms a spur of Copper Mountain (Pl. IX). The principal developments are along the crest of the ridge at an altitude of over 3,000 feet, where the discoveries of copper were first made. Prospecting on Copper Mountain began in 1897 and investigations followed the discoveries until early in 1900, when the properties were purchased by the Alaska Copper Company.

Developments were rapidly made by this company and included the construction of buildings and a large wharf. In 1902 several shipments of ore were made to the Tacoma smelter, about 500 tons in all, and they are reported to have yielded nearly $18,000. In 1903 and 1904 there was no production, and developments were

confined to the erection of a smelting plant and a power plant and the extension of a crosscut tunnel to undercut the ore body 1,000 feet below its outcrop. In October, 1905, these improvements were completed and smelting of the ore was begun.

Mine development.—The principal exploitations have been made by means of open pits or "glory holes" on New York and Indiana claims at altitudes of 3,300 and 3,500 feet, respectively. At 150 feet and 300 feet below surface outcrops two tunnel levels have been driven for undercutting. The upper level consists of 200 feet of tunneling and the second level 700 feet of tunneling with upraises to the surface. A long tunnel, including 3,000 feet of underground workings, enters the mountain at an elevation of 2,350 feet and undercuts the ore bodies at a depth of 1,000 feet. This lowest tunnel follows the contact zone of the granodiorite, first with quartzite and then with limestone. Its general course is northeasterly to a point 1,400 feet from its mouth, where it branches, the left or northwesterly branch continuing for several hundred feet along the contact to a point almost directly under the surface outcrop on the New York claim, while the northeasterly branch penetrates the massive granite belt for 700 feet toward the Indiana lode, which lies along the eastern contact.

The total mine developments at the close of 1906 are roughly estimated at 4,200 feet of tunneling and 500 feet of shaft sinking and raises, besides much open-pit work. The ore was chiefly mined from the upper workings on the New York claim and delivered to the smelter over a cable tram 6,000 feet in length.

Smelter.—The smelting plant is close to tide water at the head of Copper Harbor and consists of a 250-ton Allis-Chalmers blast furnace, ore bins of 2,500-ton capacity, coke bins of 1,200-ton capacity, and a sample mill, besides the usual appliances for the granulation and removal of the slag (Pl. X, *A*). The ore from the Copper Mountain mine is delivered to the sample-mill bin by an aerial tramway 6,000 feet long, while the ore shipped to the smelter is unloaded into receiving bunkers of 1,000-ton capacity on the wharf, and from these is drawn off into cars and hoisted on an inclined tramway to the sample mill.

In addition to the smelting plant there is a sawmill, blacksmith and machine shop, store and warehouse, assay office, and compressor plant. All of the necessary machinery at both of the mines and at the smelter is run by water power derived from Reynolds Creek. The water is transmitted 1,000 feet by a 22-inch pipe line to the compressor plant, where two water wheels develop 300 horsepower. The smelter was first operated for an experimental run in June, 1905, and since then has been operated at irregular intervals. In the summer of 1906 a large tonnage of ore was smelted with a considerable produc-

tion of matte. In October, 1906, the smelter was closed pending a reorganization of the company and no attempt was made to operate it during 1907.

Ore bodies.—Two principal ore bodies, the New York and Indiana lodes, are worked on the Copper Mountain group of claims. The outcrops are on the crest of the mountain ridge at elevations of 3,300 and 3,500 feet, respectively. Both are contact metamorphic deposits similar in mode of occurrence and origin and separated from each other by a belt of granodiorite 800 feet wide.

The ore body exposed on the New York claim occurs at the contact of the granodiorite with limestone, along which it has been exposed by a long tunnel and by surface cuts for 2,000 feet. In the tunnel the width of the deposit varies from 10 to 50 feet, and the ore is confined to the garnet-epidote contact rock. At the surface workings, however, the copper ores have been spread out into the somewhat fractured limestone hanging wall (Pl. X, *B*). This spreading is attributed to the action of meteoric waters, which has also altered the original sulphide ore into an oxide and carbonate ore, occurring in the form of pockets, small pipes, and gashes in the garnet gangue rock and in the limestone hanging wall. This action, however, has not taken place everywhere, and the unaltered sulphide minerals in the garnet-epidote gangue rock are not uncommon at the surface. Such alteration is absent at the tunnel level about 1,000 feet below the surface pit, and will probably rapidly decrease and become wanting within a few hundred feet of the surface.

The Indiana lode lies about 800 feet northeast of the New York lode and is parallel to the eastern contact of the outlying granodiorite belt indicated on the map (Pl. IX). The garnet-epidote-calcite rock and the inclosing rock extends across a width of nearly 500 feet. They are cut by a network of quartz stringers and include masses of crystalline limestone. The ore occurs irregularly and is not confined to the contact.

The present workings are on irregular ore masses near the contact, but the limits and extent of these are but little known. In origin and character of mineralization this lode is similar to the New York lode, but the values contained are lower and more scattered. The ore is composed of both carbonate and sulphide minerals of copper and contains from $1 to $2 in gold and silver values. Tunnels have been driven at points 40 to 220 feet below the floor of the surface pit in order to investigate this deposit in depth. The extension of the main tunnel at the 2,300-foot level will undercut this ore body 1,150 feet below its surface exposure. The ore from this mine is transported by a surface tram 1,400 feet in length around the south side of Copper Mountain to the head of the aerial tram at the New York claim.

A. SMELTER, TRAMWAY, AND MINE WORKINGS ON COPPER MOUNTAIN, LOOKING NORTH FROM COPPER HARBOR.

B. SURFACE WORKINGS ON CREST OF COPPER MOUNTAIN.

JUMBO GROUP.

Situation.—The claims of the Jumbo group belonging to the Alaska Industrial Company occupy the slopes of Jumbo basin on the northwest side of Copper Mountain. The claims extend from a point 500 feet in elevation and 1 mile from tide water to near the mountain summit, 3,850 feet in elevation. Two main deposits are being explored, one between 1,500 and 1,900 feet on the east slope of Jumbo basin on the Jumbo claims Nos. 1, 1A, and 2, and the other between 1,600 and 2,000 feet elevation on the Jumbo claims Nos. 4 and 14.

Development.—Investigation of the Jumbo group began in 1902, and during the succeeding years various prospect tunnels were driven and test pits sunk on the different claims. After a promising ore body was opened on the claims Nos. 4 and 14, located at 1,700 feet elevation and 8,500 feet from tide water, it was next necessary to devise a means of transporting the ore to tide water. For this purpose a Riblett aerial tram 8,250 feet long and an additional aerial tram 600 feet long were erected in 1905–6, thus connecting the beach with the lower tunnel of the mine workings, 1,700 feet above sea. At the beach a wharf with 150 feet of frontage was built and ore bins of 4,000 tons capacity erected. While this was being done developments of the ore deposits were advanced, and early in 1907 shipments of the ore to the Tyee smelter in British Columbia began.

Ore deposits.—The general rock relations of this area, which are similar to those shown at the Copper Mountain group previously described, are presented on the geologic map of Hetta Inlet (Pl. XI). The main granodiorite boss forms the foot wall of the deposit, the hanging wall being in some places a crystalline limestone and at others an altered quartzite of a banded structure, varying from a white to a reddish or greenish color.

The copper deposit being mined is on Jumbo claim No. 4, and consists of an irregular body of chalcopyrite ore 30 to 40 feet wide, 120 feet long, and about 140 feet in depth, occupying a nearly vertical position. The contact zone in which this occurs is 200 feet in width at this point, granite forming the foot wall and limestone the hanging wall. The limestone beds are fractured and faulted, and masses of this rock are completely surrounded by the garnet-epidote contact rock. Mineralized masses of garnet-epidote, completely surrounded by the limestone, are also exposed, thus suggesting a replacement of the limestone by the ore-bearing minerals. On the foot-wall side there is no definite separation between the contact rock and the granodiorite, the mineral solutions having also replaced the mineral components of this rock, though less extensively.

The contact rock has a compact felsitic texture, and is locally called felsite, though it is composed mainly of garnet and epidote.

Near the ore masses this rock becomes coarsely crystallized, the garnet and epidote form vugs of well-developed crystals, calcite occurs in small veinlets and masses, and chalcopyrite may be observed in scattered particles. Except such local changes there are no indications within the contact zone which may be used as a guide in the search for these ore masses. Those points where the limestone is in contact with the granodiorite appear to be most favorable for the occurrence of the ore deposits. Besides the minerals already mentioned scapolite, wollastonite, specularite, and molybdenite are present in small amounts.

The mine workings on Jumbo claim No. 4 consist of four tunnels between 1,550 and 1,950 feet in elevation and an open cut at 2,050 feet elevation. The main working tunnel, or tunnel No. 3, is situated at an elevation of 1,700 feet and is 280 feet in length. At a point 180 feet from its mouth a 130-foot vertical raise connects this level with the stopes in the ore body and tunnel No. 2. At a point 40 feet above the tunnel a small stope has been extended to the west on what is supposed to be the bottom of the main ore body, and 30 feet above this a 60-foot exploratory drift has been extended to the east into the ore. The floor of the main stope is 100 feet above the level of tunnel No. 3. The stope is 160 feet long, 20 to 40 feet in width, and extends for 30 feet above the level of tunnel No. 2. The ore mined goes through this raise, whence it is trammed to the upper terminal of the aerial tramway, and from there it is transported to the ore bunkers at the beach.

In Canyon Creek 200 feet to the southeast of tunnel No. 2 surface mining and exploratory tunnels are being extended on the supposed continuation of this ore body. Tunnel No. 1 at 1,950 feet elevation crosscuts the limestone for 50 feet and enters the contact rock for 15 feet, in which indications of ore are shown. Tunnel No. 4 has recently been started at a point 1,570 feet in elevation on a level with the upper terminal of the main aerial tramway. It is planned to extend this tunnel to undercut the present mine workings, with which it will be connected by a raise through which the ore will be conveyed, thus eliminating the necessity of the auxiliary tramway from tunnel No. 3.

The upper workings are on Jumbo claim No. 14 just above tunnel No. 1 at 2,050 feet elevation. These consist of an open cut and surface stripping across a width of 100 feet. The irregularity of the deposits and the sporadic occurrence of the ore is well shown here. At one point a face of massive sulphide ore 6 feet across is surrounded by the barren gangue rock; at other points sulphides were finely disseminated in the rock in sufficient amount to make a low-grade ore.

The ore body on Jumbo claims Nos. 1, 1A, and 2 is characterized by lower values in copper than in the deposit on Jumbo claim No. 4,

A. STEVENSTOWN MINE WORKINGS, SHOWING ORE BODY.

B. HADLEY, PRINCE OF WALES ISLAND, SHOWING SMELTER PLANT.

and by a large percentage of magnetite, which mineral was conspicuously absent in the former deposit. Granite forms the footwall and both limestone and quartzite the hanging-wall side. Erosion has exposed the ore body over broad areas, so that it appears to form a relatively thin covering on the granodiorite, and becomes thinner as the elevation increases. The deposit outcrops in this manner between the 1,500 and 2,000 foot contours, but above 2,000 feet granodiorite alone was observed. This contact deposit between the hanging and foot walls generally varies from 10 to 60 feet in width, but in places it is altogether absent, and the granite and limestone are in direct contact with each other, as was observed at a point a few hundred yards northwest of the workings.

The highest openings are 1,890 feet in elevation on Jumbo claim No. 1, where a small open cut exposes considerable copper carbonate ore and limonite in a banded garnet-epidote gangue. This is only a surface alteration and disappeared at a depth of a few feet. Just south of this the deposit forms a steep bluff 100 feet high and exposed over a width of 100 feet. Masses of sulphide ore accompanied by magnetite were observed along the foot of this bluff where considerable surface stripping had been done. At 1,660 feet above sea a tunnel 85 feet long running N. 30° E. crosscuts the limestone hanging wall for 20 feet, then penetrates a 10-foot band of epidote practically barren of ore, followed by 15 feet of crystalline limestone, and finally enters a belt of banded garnet-epidote rock for 50 feet without exposing the granodiorite foot wall. In the face of the tunnel small amounts of sulphide ore are scattered throughout the garnet-epidote gangue, but as a whole the rock did not appear to carry sufficient copper to constitute an ore. About 100 yards east of this tunnel, at 1,580 feet elevation, on Jumbo claim No. 2, the ore body is again exposed over a considerable area and is richer in sulphide ore. Two tunnels crosscut the ore deposit, one 1,540 feet in elevation and the other 1,480 feet. The upper tunnel starts in the deposit, penetrates it for 50 feet, and enters the granodiorite foot wall for 6 feet. The line between the ore body and the foot wall was well defined, but there was no gangue present and the ore was closely welded to the granite. Near the face of the tunnel or foot wall the ore is of a fine texture, rich in epidote and magnetite, and carries but a small amount of sulphide, whereas at the entrance to the tunnel the gangue was made up of garnet containing small masses of chalcopyrite. The tunnel just below this crosscuts the limestone hanging wall for 55 feet and enters the ore body for 9 feet. The extension of this contact metamorphic deposit on Jumbo claim No. 1A has been exposed by two tunnels, one above the other, at 750 and 840 feet elevation. The upper tunnel penetrates a banded garnet foot wall, and about 25 feet from its entrance considerable sulphide ore was exposed.

In the lower tunnel, which is 240 feet in length, the hanging wall exposed at the entrance is a reddish to dark-greenish indurated quartzite grading into the banded garnet-epidote rock near the tunnel face, where the granite foot wall is exposed. The contact metamorphic deposit at this point is nearly 100 feet wide, but the ore in it is scattered and as a whole is of lower grade than that exposed on the upper claims. The observations indicate that this deposit will be confined to the contact of the granodiorite foot wall and along this contact the occurrence of ore will be sporadic, the sulphide minerals occurring in masses or within limited contact areas connected with one another by the more or less barren garnet-epidote gangue rock. The average ore from this deposit contains a high percentage of iron and nearly sufficient silica for smelting purposes. Besides its copper content assays show values in gold and silver. The advisability of concentrating the ore by separating the magnetite from it and thus reducing its iron content is still to be determined.

GREEN MONSTER GROUP.

Situation.—The Green Monster group of claims, belonging to the Alaska Industrial Company, occupies the northern and western slopes of Green Monster Mountain, 2½ miles due east from Copper Mountain and 3 miles from the tide flats at the head of Hetta Inlet. From the latter point a trail, crossing two lakes each half a mile wide, at altitudes of 600 feet and 1,680 feet, respectively, leads to the principal mine workings at an elevation of 2,800 feet. Another approach to these claims is from Copper Harbor across a series of three lakes (indicated on the map, Pl. IX).

Development.—Although these claims were located in 1900, developments have been meager, and no attempt has been made to advance the investigation beyond the required assessment work. Two tunnels have been driven, one on Green Monster claim No. 1, 65 feet in length, the other on Diamond B. claim, also 65 feet long. On Iola claim a pit 8 feet deep has been sunk and trenches dug along the ore body.

Ore bodies.—Ore bodies at the contact of the limestone and granite are shown on the Iola, Black Warrior, and Diamond B. claims (Pl. XI). The deposit on the Iola claim has been opened by a small pit and surface stripping, and consists of a mass of magnetite-chalcopyrite ore 10 feet in width inclosed in the garnet-epidote gangue, which at this point occupies a width of about 25 feet between the limestone hanging wall and the granodiorite foot wall. Along this contact other smaller ore masses were observed on the Iola and Black Warrior No. 2 claims, but were apparently of little consequence. On the Black Warrior claims Nos. 1 and 5 similar ore bodies occur ad-

jacent to the granite and limestone contact and in a black slate band along the mountain crest striking N. 30° W., but these have not been prospected. On the Diamond B. claim a tunnel 65 feet in length has been driven along the contact of the limestone with a porphyritic dike striking N. 30° E. and 50 feet or more in width. The main contact of the granodiorite boss lies about 150 feet to the west. In this tunnel the garnet-epidote vein rock is exposed across a width of about 10 feet and for a length of 50 feet; the face of the tunnel enters the limestone. Small masses of copper sulphide occur in this contact rock, but the metal content of the vein as a whole is low.

A deposit in the form of a vein filling, occupying an irregular fissure in the limestone, occurs on Green Monster claim No. 1. This vein appears to be an offshoot from the main contact zone just west of it. A tunnel 65 feet long undercuts the vein, and for 250 feet along the surface it is exposed by trenches. The vein strikes S. 20° E. with vertical dip and averages 6 feet in width. The copper occurs in small masses and disseminated particles throughout the garnet-epidote-calcite gangue. Associated with the chalcopyrite ore is pyrite, and in places along the surface limonite, malachite, and azurite are present.

A third type of mineralization is exposed on Black Warrior claim No. 2, where a narrow vein containing galena, pyrite, and chalcopyrite has been deposited along the contact of a porphyry dike with the limestone country rock at a point about 1,000 feet from the granite contact. This ore, though of good quality, has not been found in quantity.

In general the ore bodies on the Green Monster group are similar in character to those on the Jumbo group, but from present excavations they do not appear to be as great as the latter in size and extent. The position of the property necessitates the building of a tramway over a distance of 3 miles in order to ship the ore, and conditions of mining are less favorable than at many other points along the coast.

HOUGHTON GROUP.

Situation and development.—The Houghton group of claims is located on the northwest slope of Mount Jumbo between elevations 1,000 and 2,000 feet and is 1 mile from Hetta Inlet. (See Pl. XI.) They include the granodiorite contact zone exposed on the Jumbo group to the south, and the ore bodies under exploration are of the same general type. The claims, including a mill site at tide water, were located in 1901, and from that time to the end of 1905 the developments were meager, assessment work alone being done. Early in 1906 the properties were acquired by the Cuprite Copper Company, two more claims were located, and active developments were begun. These investigations were advanced during 1907 with encouraging

results. The present mining camp is situated at 1,500 feet and the mine workings between 1,600 and 1,700 feet elevation. At 1,600 feet a tunnel, 100 feet long at the time of the visit, was being driven to explore the ore body in depth, its surface exposure being 100 feet above. At other points on these claims short exploratory tunnels and cuts have also been made.

Ore body.—The copper deposit on which investigations are being furthered is included in the garnet-epidote contact rock which occupies a zone from 25 to 75 feet in width between the granodiorite and limestone. This zone strikes N. 45° E. and dips steeply to the northwest. The ore body is developed on the surface by a 30-foot cut and a 15-foot pit, in which a body of massive chalcopyrite ore 5 feet wide is exposed. In the tunnel which enters this contact zone small amounts of copper ore are present, but the main ore body is not yet undercut. The chalcopyrite is associated with magnetite, pyrite, and some pyrrhotite. The observations in general on these claims showed a less amount of contact metamorphism and not so great a development of ore as was noted at the Jumbo group.

SULTANA GROUP.

Situation and development.—The Sultana group of six claims is located on the north side of Hetta Inlet about 1 mile east of Sulzer and extends from tide water to an elevation of 1,000 feet on the south slope of Beaver mountain (Pl. XI). The principal developments have been on the Sultana claim, though on the adjoining claims, the Index and Vulcan, prospecting has been advanced. The total workings, however, amount to little more than the amount of assessment required each year.

Ore bodies.—The ore bodies exposed are contact-metamorphic deposits underlain by a granitic intrusive, banded siliceous limestone forming the hanging wall. A gangue of garnet and epidote with considerable calcite has been deposited along the contact, in which sulphides of copper and iron are sparingly distributed in small masses and disseminated particles.

At a point on the Sultana claim 350 feet in elevation and one-third of a mile from the beach a tunnel 130 feet long was driven in the granodiorite foot wall with no result. Another tunnel 430 feet in elevation exposes at its entrance a mass of chalcopyrite ore 3 feet in width and then crosscuts the garnet-epidote gangue rock for 25 feet, showing practically no ore. On the Index claim, to the east of the Sultana claim, at 600 feet elevation, an open cut 60 feet long exposes small amounts of chalcopyrite, not sufficient to make a profitable ore, associated with magnetite and pyrrhotite in a banded garnet-epidote rock. On the Vulcan claim, north of the Sultana claim, at

an altitude of 520 feet is an open cut 60 feet wide. Here garnet-epidote rock occurs with large included fragments of banded limestone containing pyrrhotite and chalcopyrite in masses a few feet wide. A relatively small amount of ore is developed on these properties, but future explorations may reveal new and larger bodies. The ore at this prospect was reported to carry cobalt in considerable amount, but a sample taken by the writer and submitted for analysis gave only a trace of cobalt and less than 0.2 per cent of nickel.

CORBIN MINE.

Situation and development.—The Corbin mine is close to tide water on the east side of Hetta Inlet, 1½ miles north of the entrance to Copper Harbor. This property of four claims was located in February, 1905, and the following summer ore shipments were made to the smelter at Coppermount. Early in 1906 the mine was sold to the Alaska Metals Mining Company, which began active development and equipped the property with an air compressor, a hoist, a steam-power plant, and erected a small wharf and various buildings. The position of the ore body necessitated the sinking of a shaft 100 feet, and at this depth considerable crosscutting and drifting were extended to investigate the ore body at this level. Adjacent to the shaft a tunnel has been driven along the vein for 210 feet, but the results were not encouraging. Operations on this property were suspended during the winter of 1907 and have not since been renewed.

Ore bodies.—The ore body is a vein deposit of nearly massive sulphide ore inclosed in a narrow fissue parallel to the stratification of a greenstone-schist country rock. The vein is from 1 foot to 3 feet in width and has been exposed about 250 feet in length, striking N. 70° W. and dipping 70° SW. A tunnel 210 feet in length was driven along the vein to the southeast and in this the vein narrows to a thin gouge seam and widens again at several points, its continuation being indicated by the bleached appearance of the country rock. The foot wall of the vein is a dark-green schist and appears less altered than the hanging wall, which is a pale-green talcose schist. Grooves caused by slipping were observed on both the foot and the hanging wall. These grooves pitch 50° NW., and this is the direction that the ore shoots are most likely to follow. In the vein itself occasional slickensides were observed, indicating movement along these lines since the deposition of the ore. Dikes of diabase from 2 to 4 feet in width, striking N. 10° E. and dipping 70° NW., nearly at right angles to the prevailing rock structure, crosscut the vein deposit. The ore is principally pyrite containing chalcopyrite associated with some ouartz and calcite as gangue minerals. Besides the small per cent of copper in the ore, gold and silver amounting to about $3 in

value per ton are reported. At other points on these claims exploration may reveal vein deposits similar to the one described.

COPPER CITY MINE.

Situation and development.—The Copper City mine, also known as the Red Wing group, consisting of four claims, is situated close to tide water on the east side of Hetta Inlet, 7 miles south of Copper Harbor. This property, because of its position and the character of the deposit, has been a copper producer in a small way ever since operations first began in 1903, the ore being sacked and shipped to the Tacoma Smelter. The developments have been confined to the Red Wing claim, where the vein deposit has been opened by an inclined shaft 120 feet in depth. From this shaft two levels, 50 feet and 100 feet respectively in depth, have been extended. The 100-foot is the working level and this has been extended along the vein for 200 feet to the north and for 50 feet to the south of the shaft. At a point on the level 75 feet north of the shaft a 60-foot winze has been sunk and from this a drift 50 feet long has been extended. Most of the ore above the 100-foot level has been mined, and it is proposed to sink the shaft an additional 100 feet and open up a 200-foot level.

Ore body.—The ore body, a vein deposit of nearly massive sulphide ore, is inclosed in a slate-greenstone country rock parallel to the bedding plane and corresponds in general character to the ore body at the Corbin mine already described. The country rock grades from a black slate or siliceous schist to an amphibole schist or altered greenstone, the general strike being N. 20° E. and the dip 60° NW. Cross-cutting these schists and also the vein deposits are several diabase dikes 1 foot to 5 feet in width, striking in a N. 30° W. direction. These dikes were intruded after the main ore deposition, but subsequent mineralization has deposited small amounts of mineral in veinlets entering them, and the ore bodies, where crosscut, usually continue along the same line of strike on opposite sides of these intrusives. The vein as exposed in the shaft varies from 6 inches to 4 feet in width, narrowing to a gouge seam at 100 feet in depth. At this level the vein appeared to be displaced for a short distance toward the foot-wall side, where it was again found, and on it the 60-foot winze was sunk, in which the vein was reported to have a considerable width. Smaller veins of similar character and parallel to the main vein have been exposed by surface cuts and trenches at other points on the property, but none of these have been developed.

The ore is composed essentially of chalcopyrite, pyrite, sphalerite, and rarely hematite (specularite), associated with quartz, calcite, and epidote as gangue minerals. Surface oxidation has altered the chalcopyrite in places to limonite and cuprite, and along jointing cracks

in the country rock malachite and small films of native copper were observed. Besides the copper content, the ore contains values in gold amounting to $3 to $6, and silver amounting to $1 to $3, besides from 6 to 9 per cent of zinc.

PROSPECTS ON GOULD ISLAND.

Gould Island, which occupies the head of Hetta Inlet, is about 2 miles in length and less than 1 mile wide. It is composed essentially of limestone, siliceous schists, and slate intruded by a granodiorite mass which occupies the eastern portion of the island (Pl. IX). The prospects are located at the southwest end of the island. The ore which consists of galena, spalerite, and chalcopyrite, occupies small veinlets, and is finely disseminated in a belt of siliceous limestone 30 feet wide, striking east and west, with a steep dip to the north. Associated with the ore are calcite, quartz, garnet, epidote, and large amounts of wollastonite, the latter occurring in the adjacent limestone in radiating masses. A tunnel 70 feet long has been driven along the foot wall of this mineralized belt, where it is in contact with slate, and scattered occurrences of ore are shown. Just north of the tunnel is an open cut and a shaft 10 feet deep, exposing mineralized rock of the same character. About 300 feet east of these workings is another open cut and a pit 10 feet deep on the same belt. The amount of ore exposed on these claims at the time of the writer's examination was small and of low grade.

PROSPECTS AT HEAD OF COPPER HARBOR.

The prospects at the head of Copper Harbor indicated on the map, excepting the Paris vein, are all contact-metamorphic deposits and lie adjacent to the same granodiorite batholith exposed on the Copper Mountain and Jumbo groups (Pl. IX). On none of these claims have the developments exceeded the assessment requirements. On the Paris group of claims, located at 300 feet elevation, about a half mile from the beach, a tunnel 115 feet in length has been driven along a small quartz vein 1 foot wide striking northeasterly and containing low values in copper and gold. The country rock is a banded quartzite striking N. 40° W. and dipping 40° to 60° SW. The Gould group, which lies north of Reynolds Creek and at 300 feet elevation, one-half mile from Copper Harbor, is located along the granodiorite contact with quartzite which at this point strikes S. 20° E. A tunnel 50 feet long crosses the contact rock and enters the granite, which also carries small amounts of chalcopyrite and pyrrhotite scattered near the contact in fine particles. A 40-foot shaft at the mouth of the tunnel exposes the mineralized garnet-epidote rock, showing a banded structure striking parallel with the contact and dipping 60° SW. About a mile northeast of the Gould group and

at 100 feet elevation is the Russian Bear claim, and adjoining this on the north the Texas claim at 1,450 feet elevation. The contact-metamorphic deposits on both these claims flank the western slope of the granodiorite batholith, and the developments consist mainly of open cuts and trenches, in which only small ore masses have been exposed.

PROSPECTS ON HETTA MOUNTAIN.

Hetta Mountain, which lies southeast of Copper Harbor, is made up essentially of limestone and quartzites, its northern slope, as indicated on the map (Pl. IX), being bordered by the granodiorite intrusive. Two claims have been located on contact deposits similar to those described along the intrusive contact about 1 mile from Copper Harbor and at 900 feet elevation. The ore bodies have been prospected by three tunnels, one 20 feet, one 25 feet, and one 30 feet in length, and several open cuts in which small masses of chalcopyrite and pyrrhotite are exposed in the garnet-epidote contact rock. The quartzitic schist country rock to the south, which forms the hanging wall of the deposits, strikes east and west with nearly vertical dip, and is intersected by granitic and pegmatitic dikes.

In a gulch at 1,380 feet elevation another prospect is located on a vein deposit consisting of garnet with some epidote and sulphide ores in the siliceous schists. At this point a tunnel 30 feet long has been driven along the vein and at the entrance a small mass of chalcopyrite ore is exposed. On the ridge of Hetta Mountain the quartzites alternate with limestone strata having a N. 80° E. strike, and intruding these beds are occasional masses of granodiorite. Along the contact of one of these dikes at 2,480 feet elevation, on the north slope of the ridge, a contact-metamorphic deposit occurs which contains both the sulphide and the carbonate ore of copper. A tunnel 15 feet long and considerable stripping constitute the developments and expose small masses of the copper ore in a garnet gangue. Southeast of this prospect on the opposite side of the ridge, at 2,500 feet elevation, an iron capping has been explored by trenches, and in these also small amounts of copper ore are exposed.

KASAAN PENINSULA.

GENERAL DESCRIPTION.

Kasaan Peninsula is a promontory on the east side of Prince of Wales Island 18 miles in length and from 3 to 6 miles wide, projecting into Clarence Strait and sheltering Kasaan Bay (see fig. 1, and map, Pl. I, in pocket). It is a steep, heavily timbered mountain ridge with summits reaching altitudes of 1,000 to 3,000 feet. The range is dissected near the center of the peninsula by a low pass 400

feet at its highest point, extending from the "Hole in the Wall" to a point 3 miles southeast of Kasaan village. At the northeastern end of the peninsula is also a broad, low marshy valley 4 miles in length, extending from the head of Tolstoi Bay to a point 3 miles northwest of Kasaan, and another low pass 3 miles long from the head of Thorne Bay to the east side of Karta Bay. The timber on the peninsula extends to an elevation of from 1,500 to 1,800 feet, below which

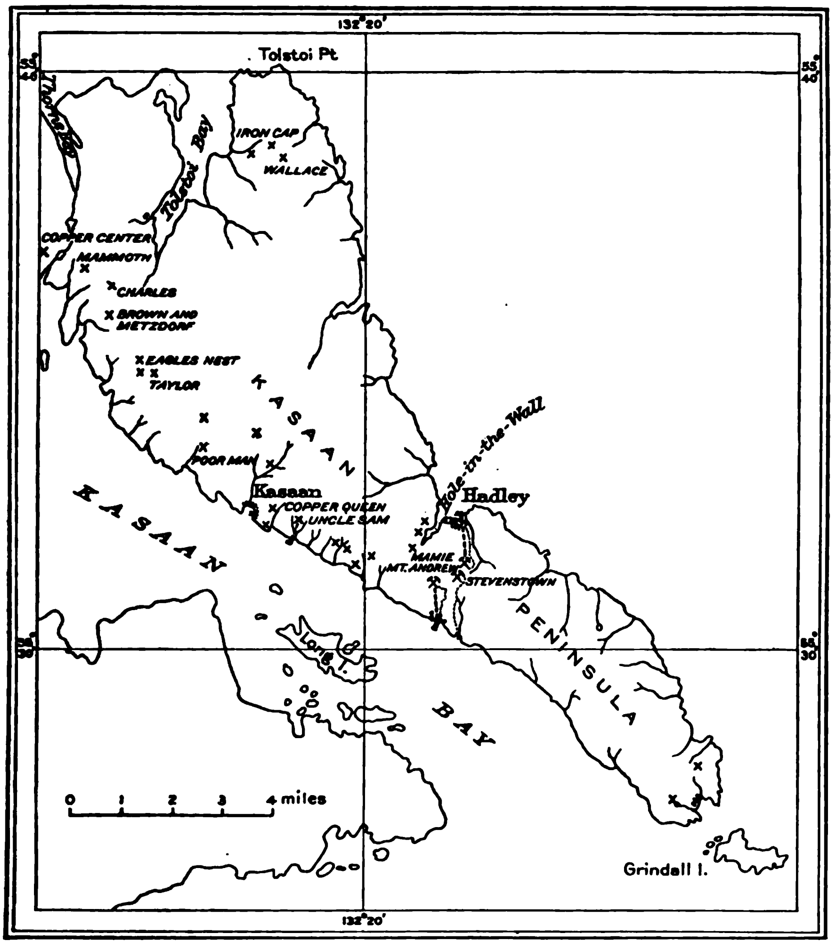

FIG. 1.—Map of Kasaan Peninsula, showing mine locations.

a dense undergrowth renders prospecting difficult. The summits of the ridges are open except for small clusters of scrubby pine.

The relief of the peninsula is typical of the more mature topography of the islands as compared with the rugged, more abrupt topography of the mainland. The mountain summits are dome shaped and on them are large erratic bowlders, an evidence of glaciation.

The valleys, which extend northward from near the head of Kasaan Bay, are broad and contain many lakes, and in them are deep deposits composed of large and small bowlders embedded in glacial clay. The islands and shoals at the entrance to Karta Bay are made up entirely of these glacial deposits and represent the end moraines left by former ice fields.

The occurrence of copper on Kasaan Peninsula was known to the Russians as early as 1865, but not until 1900 did active mine developments begin. It is now the principal copper-producing area in southeastern Alaska.

GEOLOGY.

Kasaan Peninsula is composed largely of underlying intrusive rocks, including granodiorite, syenite, hornblende diorite, and more rarely granite. These rocks invade limestone beds and strata of highly altered sedimentary and pyroclastic rocks ranging from greenstone tuffs to sandstones and conglomerates composed principally of igneous material.

Stratified rocks.—The stratified rocks include those of sedimentary and volcanic origin. They occur principally on the northern portion of the peninsula and adjacent to Tolstoi and Thorne bays, and are made up of a series of metamorphosed bedded rocks altered to hornfels and mica schists and often highly epidotized and containing amphibole and pyroxene crystals. These range in texture from fine-grained tuffs, slates, and sandstones to coarse conglomerates. The conglomerates contain many fragments and pebbles of igneous rocks as well as of limestone and quartzite. The sandstones and greenstone tuffs are composed largely of volcanic material, and because of their induration they closely resemble massive igneous rocks. In most places their fragmentary character may be recognized. The limestone beds exposed on the peninsula are entirely recrystallized, and both evidence of structure and organic remains are lacking. They are of importance because of their association with and relation to the ore deposits. Limestone beds, conformably underlain by sandstones composed largely of igneous material, occur on Long Island, which occupies the central portion of Kasaan Bay and lies 1 mile southwest of Kasaan Peninsula. Interstratified in these limestone beds near their contact with the underlying rocks are thin beds of sandstone and conglomerate, most of the pebbles in the latter being of porphyry. In the limestone beds themselves Devonian fossils are abundant; collections in this locality were first made in 1901 by Brooks, and in 1905 a more complete collection was made by E. M. Kindle. Because of the analogy of these rocks to those on Kasaan Peninsula, the latter are provisionally considered to be Devonian.

The structure of the sedimentaries exposed on Long Island is of interest because of the two systems of folding represented, an

older system of small folds with a northeasterly strike and a later system of broader folds which trend to the northwest and belong to the main system of the Coast Range. On the peninsula the structure of the bedded rocks has been so greatly interrupted by the intrusive masses that no persistent lines of strike and dip could be followed, though the most prominent direction of the bedding planes was from northwest to west with a steep dip to the southwest. Two prominent jointing systems are also present on the peninsula, the one striking N. 15° to 25° E. with a dip 60° to 80° SW. and the other striking N. 50° to 70° W. with a steep dip to the northwest.

Intrusive rocks.—The intrusive rocks occurring on Kasaan Peninsula all invade the sedimentary strata and are therefore of more recent age. The principal intrusive, however, is the granodiorite which forms the entire southern portion of the peninsula and occupies wide areas in the central and northwestern portions. But little is known of the rocks that were intruded into this area previous to the granodiorite, this being the oldest intrusive rock recognized. The granodiorite intrusives, however, vary considerably in composition and probably represent several periods of igneous invasion during one general epoch, though in some instances this difference can undoubtedly be attributed to segregations within the igneous magma during solidification. After the intrusion of the granodiorite, granite and syenite dikes or masses many hundred feet in width were intruded, besides numerous pegmatite and aplite dikes. Somewhat later or possibly during the same period rocks more basic intruded the area in the form of dikes. These were followed by felsitic dikes from one to several hundred feet in width. Still more recent are the diabase and basaltic dikes, all of which are later than the ore bodies.

ORE DEPOSITS.

The occurrence of ore on Kasaan Peninsula is similar to that in the vicinity of Hetta Inlet. The ore bodies are contact-metamorphic deposits occurring usually at the contact of an intrusive syenite mass with limestone and in some places with greenstone tuff or conglomerate. They are included in a garnet-epidote gangue and are generally associated with magnetite, this mineral forming in many places half of the gangue. The principal mineral zone defined on this peninsula follows the contact of a syenite intrusive mass with a narrow belt of limestone, and is traceable from the east side of Mamie Creek for 2 miles in a westerly direction. This zone ranges from 100 to 300 feet in width, though because of its flat dip and its conformity with the contour of the mountain slope it appears locally to be much wider. The Mamie, Stevenstown, and Mount Andrew mines are included within this zone. Another smaller belt of contact deposits

appears to follow along the western side of the peninsula about 1 mile inland, beginning 3 miles northwest of Kasaan and continuing northwestward to Karta Bay. The Sea Island, Haida, and Coppercenter prospects are included in this belt. Besides the contact-metamorphic deposits, copper ores associated with quartz are found occupying sheer zones in the greenstone tuffs and conglomerates at the head of Karta Bay, namely, in the Rush & Brown mine and at the Venus prospect. On the east side of Karta Bay bornite and chalcopyrite occur in small masses and are disseminated throughout a basic diorite intrusive belt on the Goodro and Stevens prospects. Vein deposits containing essentially silver-lead ores occur in the limestones northeast of Kasaan.

The persistency of these various ore bodies depends largely upon the type. The contact deposits are generally irregular masses of small extent as a rule and no more persistent in depth than they are laterally; but where the contact zone is extensive, investigations within it will probably reveal similar ore masses both laterally and in depth. The copper-iron sulphide deposits in shear zones in the stratified rocks are more persistent than the contact ore bodies and will probably extend to a considerable depth. The vein deposits in the limestones will also be extensive in depth, but will vary considerably in width, often narrowing to a mere seam.

To judge from analogous deposits of the latter type, it is possible that the lead-silver ores will be replaced by copper ores in depth.

MAMIE MINE.

Situation and development.—The Mamie mine, owned by the Brown Alaska Company, is situated 1¼ miles south of Hadley, at an elevation of 700 feet, in the central portion of Kasaan Peninsula (figs. 1 and 2). The mine workings are connected with the smelter at Hadley by an aerial tram 5,500 feet in length and with the beach by a horse tram 7,700 feet in length. The horse tram is used for the transportation of supplies. Mine developments in a large way were not begun until 1904. During that year the ore bodies were explored by numerous open cuts, tunnels, and diamond-drill holes. In the following year mining of the ore was begun from the open pits and new ore bodies were developed by tunnels and shafts. At the close of 1905 considerable ore was delivered to the smelter, and throughout 1906 the production was large. In 1907 diamond-drill investigations were advanced, new ore bodies were located at greater depth, and the ore production continued with little interruption until late in September. In October all operations were suspended. The total developments consist of 5,000 feet of tunneling, drifting, and crosscutting and about the same amount of diamond-drill prospecting.

The smelter or reduction plant at Hadley, belonging to the Alaska Smelting and Refining Company, is controlled largely by the owners of the Mamie mine (Pl. XI, *B*). It consists of a blast furnace of

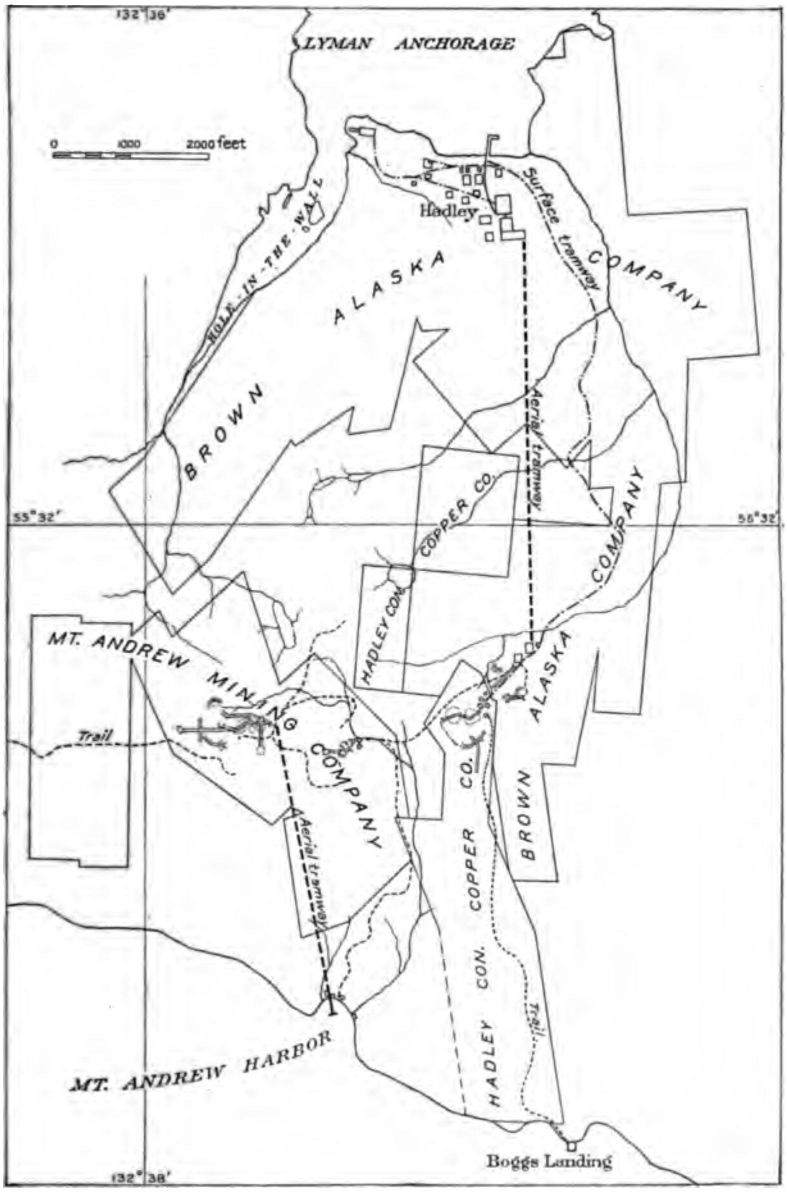

FIG. 2.—Map showing properties of the Brown Alaska Company, Hadley Consolidated Company, and the Mount Andrew Mining Company.

350 tons daily capacity, a sampling mill, coal and coke bins, ore bunkers of 10,000 tons capacity, boiler house, engine house, electric-

light plant, and other conveniences. The ores from the Mamie and Stevenstown mines first go through the samplers, next to the ore bunkers by gravity, and thence by gravity to the furnace. The slag from the furnace is granulated and carried by water to the beach. A cable tramway extends from the wharf to bins above the sampling mill, which have been built to receive custom ore. The plant is so arranged that its daily capacity may be doubled if necessary. Smelting operations began December 5, 1905, and in 1906 the furnace was in blast about twenty days each month. In September, 1907, this plant was closed.

Ore bodies.—The ore bodies at the Mamie mine are contact metamorphic deposits included in a zone 400 feet wide lying between a syenitic intrusive and limestone. Within this zone the masses of valuable copper ore are defined either by such a decrease in the copper content of the inclosing rock as to prohibit profitable extraction or by fault planes. Garnet, epidote, and magnetite compose the contact rock. Chalcopyrite is present throughout in small quantities. The ore bodies or portions of the contact rock where the concentration of the copper values is sufficient to make ore are irregular masses ranging from 50 to 100 feet in length and thickness and from 10 to 40 feet in width, the major axis striking northward. Nine such ore masses are exposed in the mine workings. Some of them are included entirely in magnetite masses, thus making basic ore, while others occur in the garnet-epidote gangue rock, making a siliceous ore. Small veinlets of calcite and rarely quartz intersect the ore masses, thus indicating a later period of mineral deposition, though the main ore deposits are believed to have been deposited contemporaneously with the inclosing contact rock.

STEVENSTOWN MINE.

Situation and development.—The Stevenstown mine, owned by the Hadley Consolidated Copper Company, is situated just above and southwest of the Mamie mine at an elevation of 1,000 feet (fig. 2). From the mine a surface tram 700 feet long connects with the aerial tram at the Mamie mine, over which the ore is transported to the smelter at Hadley. A trail also leads from the mine down the south side of the peninsula to Boggs Landing, on Kasaan Bay, a distance of 1 mile. The mine has been developed by three "glory holes" or open pits connected by raises with a 550-foot tunnel penetrating the crest of the mountain. Actual mining developments were first begun in June, 1905, previous to which time prospecting alone had been carried on, and in September of that year ore shipments to the Hadley smelter began. A large amount of ore was produced during 1906, and until the first of July, 1907, when mining operations were suspended.

Ore bodies.—The ore bodies on the Stevenstown property correspond both mineralogically and genetically with those at the Mamie mine (Pl. XI, *A*). They occupy a relatively flat position on the crest of the mountain ridge and are apparently underlain by the syenite intrusive which forms the foot wall of the mineral belt and which is exposed throughout the tunnel that penetrates the mountain top. The hanging wall as well as a large portion of the ore bodies on this property have been removed by erosion and the contact zone is only from 20 to 40 feet in width instead of 200 to 400 feet, the width on the Mamie property just below. To the northeast of the ore bodies strata of limestone and greenstone tuff occur and continue westward toward the Mount Andrew mine, forming the hanging wall of the mineral zone.

The mine workings are all surface pits connected by raises with the main tunnel, and in these several relatively flat-lying ore masses have been developed. These masses are included within an area 350 by 200 feet, the pits being from 20 to 40 feet deep. The central portion of this area is traversed in a southerly direction by a 40-foot felsite dike, which is of later intrusion than the syenite and crosscuts the ore body. Smaller dikes of diabase and basalt 1 foot to 5 feet in width were observed crosscutting the ore bodies and country rock at several points in these mine workings.

The ore is composed largely of magnetite, chalcopyrite, and pyrite associated with hornblende and calcite, all of which are included in a more or less banded garnet-epidote gangue.

Surface oxidation has produced considerable limonite and some malachite and azurite; small particles of native copper also occur along slipping planes, though these secondary minerals are relatively unimportant.

MOUNT ANDREW MINE.

Situation and development.—The Mount Andrew mine workings are situated three-fourths of a mile from Mount Andrew landing on the southwest side of Kasaan Peninsula and one-half mile west of the Stevenstown mine, at an elevation of 1,400 feet. A cable tramway 3,600 feet long leads from the mine over a 1,440-foot knoll just south of the workings to the ore bunkers and a wharf at Mount Andrew landing (fig. 2).

This mine is developed principally by a tunnel 620 feet long, undercutting the ore bodies from 60 to 100 feet or more in depth. From this tunnel several hundred feet of drifting and crosscutting have been driven, and upraises extended through the ore bodies to the surface. The ore is mined out of large underground stopes and from surface pits or glory holes, and is delivered through chutes at tunnel level to the ore bunkers at the head of the aerial tram and thence

carried to the wharf, where it is loaded for shipment. Developments in a large way were not begun until late in 1905, and during 1906 the aerial tram was erected, the wharf built, the compressor plant installed, and considerable ore developed. The first ore shipments were made in October, 1906, and production continued until October, 1907, when operations were suspended.

Ore bodies.—The ore deposits on this property are included in the same mineral belt as those at the adjacent Mamie and Stevenstown mines, with which they are in every way comparable. Six ore bodies

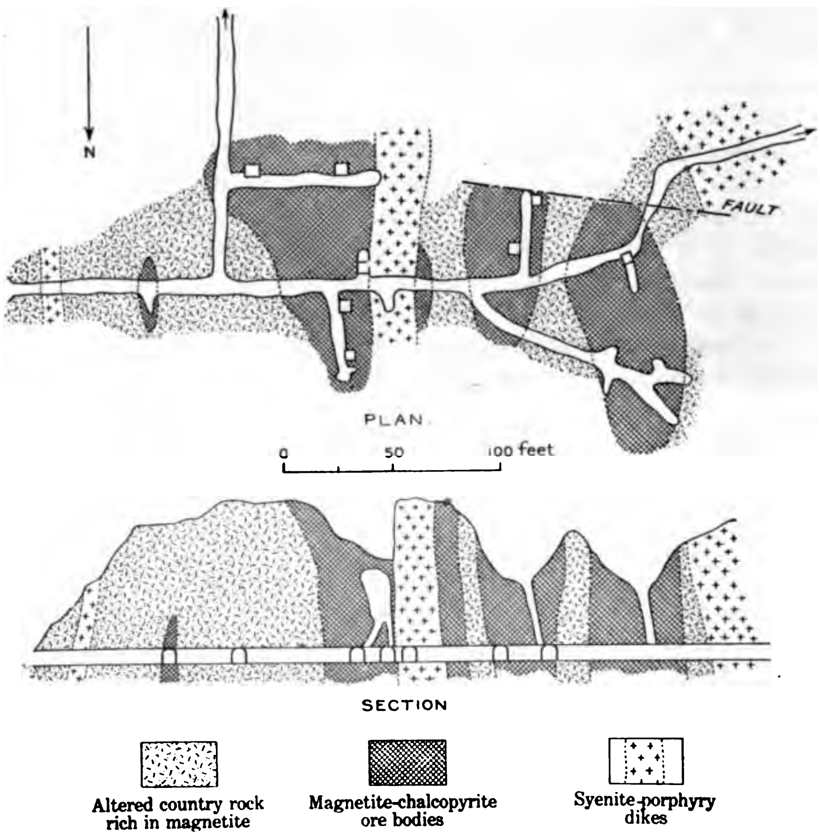

FIG. 3.—Plan and cross section of Mount Andrew mine workings, showing positions of ore bodies.

consisting of irregular magnetite-chalcopyrite masses associated with the garnet-epidote contact rock have been developed and mined to a considerable extent. These bodies of ore are from 10 to 50 feet wide, 40 to 80 feet long, 100 feet or more in depth, and have a general northerly strike and pitch. They are separated by barren areas of contact rock and dikes 20 to 60 feet of altered syenite porphyry (fig. 3). The mine workings consist essentially of surface pits which are undercut by a crosscut tunnel running east and west. This tunnel

with connecting drifts and raises includes 2,200 feet of underground developments. Numerous gouge seams and slickensides indicating faulting were observed in the mine workings, and lateral displacements of the ore bodies from 1 to 6 feet were noted. Dikes of diabase and felsite from 2 to 12 feet wide crosscut the ore bodies and country rock in various directions and were evidently intruded later than the formation of the ore deposits.

At other points on Mount Andrew large masses of the magnetite carrying but a small percentage of copper, insufficient in amount to make a copper ore, have been developed. These deposits, though not valuable for copper alone, may at some future time be of importance as a source of iron ore.

UNCLE SAM MINE.

Situation and development.—The Uncle Sam mine, originally called the White Eagle group, lies 3 miles northwest of Mount Andrew landing and one-half mile from Kasaan on the south slope of Kasaan Peninsula (see fig. 1). The mine workings are 430 to 550 feet in elevation and less than half a mile from the beach. Mining operations have been advanced on this property at various intervals since its discovery in 1899, and in 1901 an aerial tram, ore bunkers, and a wharf were built. Early in 1906 a shipment of ore was made, but no further work was done until March, 1907. At that time operations were renewed, continuing until July, when another ore shipment was made. The mine is developed by a tunnel and drifts, amounting to about 800 feet in length, and by open pits exposing the ore body on the surface above the tunnel. From this working tunnel a surface tram, 1,150 feet long, conveys the ore to the wharf.

Ore body.—The ore body exposed in the tunnel consists of an irregular lens of chalcopyrite-pyrite ore 6 to 8 feet in width, striking north and south and pitching about 45° N. It is cut off to the north by an east-west fault dipping 80° N., which shows but a small amount of gouge. At the open cut above the tunnel similar masses of ore are exposed, but no large ore bodies have been defined. Garnet, epidote, magnetite, and calcite occur as gangue minerals and in many places form small geodes. The chalcopyrite ore contained in this gangue rock is irregularly distributed in small masses and not along definite lines. The country rock is made up of strata of chloritized and epidotized greenstone tuff which are underlain by the intrusive syenite and are crosscut by small dikes of diabase, of later origin than the ore bodies.

COPPER QUEEN GROUP.

The Copper Queen group of claims, which represent the first copper locations on Prince of Wales Island, lies about one-half mile southeast of Kasaan. In 1898 these claims were sold to the Kasaan

Bay Mining Company, which made additional locations. Small operations were in progress from 1899 until 1902, and 500 feet of tunneling was done besides surface excavations. Since 1903 the property has been idle.

The principal ore deposit is exposed along the side of a gulch at a point 300 feet in elevation. It consists of an irregular mass of chalcopyrite ore accompanied by pyrite and magnetite in a garnet-epidote gangue, at the contact of an altered intrusive syenite with the greenstone tuff. Below these exposures a crosscut tunnel 400 feet in length has been driven in the altered syenite, but has failed to reveal any ore.

Other mineral exposures occur on these claims at points close to tide water and have been prospected by shafts and open cuts, but so far no important deposits have been discovered.

POOR MAN'S GROUP.

The Poor Man's group of two claims is located 2 miles northwest of Kasaan (fig. 1). The mine workings are connected with deep water by a surface tramway and wharf, having a total length of about 2,000 feet. The principal developments are at the head of the tramway and consist of a tunnel driven 90 feet in a southwesterly direction, which crosscuts a 40-foot body of magnetite ore and 30 feet of garnet-epidote contact rock, and at its face enters a wide dike of red syenite for 20 feet. At a point 80 feet from the mouth of the tunnel is a vertical shaft extending 30 feet to the surface and 60 feet in depth. This body of magnetite is exposed on the surface above the tunnel, and similar masses have been prospected by short tunnels and cuts and shafts at points along the tramway and on adjoining properties. Associated with the magnetite are large amounts of calcite and hornblende, some pyrite and chalcopyrite, and garnet and epidote. Although the magnetite deposit itself is extensive, the chalcopyrite ore occurs only in isolated pockets or narrow veinlets and is not disseminated throughout the magnetite in sufficient amounts to make a copper ore of the entire body. It is noteworthy, however, that these ore bodies may be of value for their iron content. Minor displacements, due to faulting on slipping planes, and dikes of diabase and felsite crosscutting the deposits were noted.

EAGLE'S NEST GROUP.

The Eagle's Nest group of claims, situated 4 miles northwest of Kasaan, was first located in 1906, and in the same year was bonded to the Sea Island Copper Mining Company. Operations by this company were begun in October, 1906, and continued in a small way until September, 1907, when the property reverted to the owners.

The developments have been confined to the mineral exposures on the Alarm claim at an elevation of 400 to 500 feet. On the southeast end of this claim is a 70-foot tunnel essentially in a garnet-epidote rock in which a small amount of ore occurs near the face. Just above the tunnel a body of magnetite-chalcopyrite ore 8 feet wide and 20 feet long is exposed in an open cut, beneath which are beds of limestone. Above this near the summit of the ridge is an open cut and shaft 12 feet deep exposing small amounts of ore associated with garnet in limestone. On the northwest end of this claim an open cut and a shaft 35 feet deep expose masses of chalcopyrite associated with various contact minerals in a coarsely crystalline limestone. Above the latter workings diorite is exposed and forms the upper portion of the ridge. No large copper deposits have been developed on these claims, though further investigation may reveal important ore bodies.

TAYLOR PROSPECT.

The Taylor prospect, located early in 1907 as the It claim, adjoins the Eagles Nest group on the east. On this prospect, at a point 600 feet in elevation, a body of chalcopyrite ore in a gangue of garnet and epidote has been exposed by surface cuts over an area of 20 by 40 feet. The ridge to the southwest or the foot-wall side is composed of diorite, and below the prospect to the northeast limestone beds are exposed.

MAMMOTH GROUP.

Situation and development.—The Mammoth group lies on the east side of Karta Bay, about 6 miles from Kasaan and one-third of a mile from tide water on the top of a low hill 500 feet in elevation (fig. 4). The property was largely developed in 1904–5 by the original owners and in June, 1906, was sold to the Haida Copper Company, which began active developments and made plans for the erection of a gravity tram 2,000 feet in length to the beach and for a wharf and ore bunkers. In April, 1907, these improvements were completed and the company made shipments of ore to the Hadley smelter. Early in the summer, however, operations were suspended, and the mine has since been idle. The mine is developed by a tunnel 120 feet in length connecting with a shaft 35 feet deep, which in turn connects with a surface pit on the ore body. Exploratory drifts have been extended from the tunnel, and prospect pits and short tunnels have been driven at other points on the property.

Ore body.—The ore body is an irregular magnetite mass carrying chalcopyrite in a gangue of garnet and epidote. The country rock in the immediate vicinity is made up of greenstone, tuff, and con-

glomerates, though just below the mine workings a belt of intrusive diorite is exposed which forms the western half of the ridge and probably underlies the ore body. The deposit is developed by an open pit over an area about 50 feet in diameter. This is undercut by a tunnel at a depth of 30 feet, and though the magnetite is exposed at this depth, chalcopyrite is not so abundant. To the northeast the ore body is limited by a fault plane striking nearly east and west and dipping 75° S. Other slipping planes striking at different angles were noted in the ore body and inclosing rock.

OTHER PROSPECTS.

Copper Center group.—The Copper Center group of claims lies 1 mile north of the Mammoth group at an elevation of 400 feet. It was located in April, 1907, and in July was bonded to mining men who undertook its development. Several shafts from 10 to 30 feet deep were sunk within an area 300 by 120 feet. In all of these shafts and surface cuts a magnetite and chalcopyrite ore associated with garnet-epidote and hornblende gangue is exposed. The deposit is apparently flat-lying, though the amount of work done is hardly sufficient to prove that it does not continue in depth. It is also probable that further investigations at a greater depth will reveal deposits at other points on the property. The country rock is largely greenstone tuff and conglomerate which is underlain by the granodiorite exposed down the hillside to the southwest. The area is densely covered by an undergrowth which renders prospecting difficult. The dip needle has been successfully used within this area and the deposit just described was located by it.

Charles prospect.—The Charles property lies about 1 mile southeast of the Mammoth group at an elevation of 380 feet and 5,000 feet from tide water. It was located in May, 1907, and only a small amount of work has been done on it. The mineral body exposed in a cut 20 feet long and 10 feet deep consists of chalcopyrite masses associated with some magnetite in a garnet gangue which replaces the greenstone tuff country rock.

Granodiorite composes the hill just west of this prospect, but was not exposed near the mineral body. Dikes of diabase crosscut the ore body and are evidently of later intrusion. Besides the values in copper, the ore is said to carry high values in both gold and silver.

Brown & Metzdorf prospect.—The Brown & Metzdorf prospect is located three-fourths of a mile south of the Charles prospect and one-half mile from Kasaan Bay, at an elevation of 310 feet. The ore body is a mineralized mass of garnet rock carrying chalcopyrite and pyrite exposed over a width of 10 feet, showing a banded structure and evidently replacing the bedded quartzite and greenstone tuff coun-

try rock. A wide belt of limestone is exposed in bluffs along the trail just below this prospect.

Peacock and Tacoma claims.—These claims, about 3 miles southeast of Kasaan post-office, are the property of the Grindall Mining and Smelting Company (fig. 1). The Tacoma claim is located along the beach, where open cuts have been made on ore exposures that are covered at high tide. The ore is confined to the garnet-epidote rock and occurs in irregular patches or is finely disseminated, but nowhere in large bodies. In the beach cuts a small amount of ore is exposed, and above this at an elevation of 50 feet is a tunnel 60 feet in length entering the hill in a northeasterly direction. This tunnel crosscuts a wide belt of garnet-epidote rock containing some chalcopyrite. Other open cuts expose small amounts of ore at several places, but no large ore masses have been developed.

The Peacock claims adjoin the Tacoma claim on the north and continue to the center of the peninsula. At a point 600 feet from the beach and 120 feet above tide a tunnel 45 feet long exposes a belt of garnet-epidote contact rock containing magnetite and a small amount of chalcopyrite. Still higher, at 325 feet, a second tunnel 30 feet long, following the contact of a diabase dike, exposes a similar mineral-bearing rock. Here also dikes of felsite and basalt occur, and slipping planes fault the mineral body in various directions. The amount of development on these properties has not been sufficient to disclose ore bodies large enough to justify mining, but systematic prospecting may open up deposits of value.

"*Hole in the wall*" *prospects.*—The small cove known as "Hole in the wall" lies on the north side of the harbor at Hadley, and along its shores and west of it a number of claims have been located, among which are the Plumley group and the Eureka, Sunrise, Pennsylvania, Venus, and Pelaska claims (fig. 1). On the Hilma claim of the Plumley group, at a point one-half mile northwest of the head of the cove and 310 feet in elevation, a tunnel 25 feet in length has been driven along the contact of an altered limestone belt with a dioritic intrusive, in which small masses of chalcopyrite are exposed in a garnet-epidote-calcite contact rock. On the Eureka claim at tide water similar contact deposits are being developed and are reported to be of considerable extent. The Sunrise claims, three in all, are located west of the "Hole in the wall," and on these claims at points along a gulch small ore masses occur replacing limestone beds at or near their contact with granodiorite. At 1,050 feet elevation this contact aureole is 25 feet in width and contains considerable magnetite and chalcopyrite ore which shows much surface alteration. On the south slope of the hill at 950 feet elevation is an open cut exposing a highly crystalline marble, slightly banded, striking N. 65° E. and dipping 60° NW. This marble overlies the contact rock which

carries small amounts of the copper ore. On the Pennsylvania claims southeast of the Sunrise claims an open cut following a felsite dike at 850 feet elevation exposes a small vein 2 to 3 feet wide consisting of pyrite with small amounts of chalcopyrite. The prospects on the Venus claims show contact deposits similar to those exposed on the Sunrise claims to the north and are apparently along the same intrusive contact. The Pelaska claim, extending from the head of the cove westward, has been developed by a tunnel over 100 feet in length following a belt of altered limestone intruded by a diabase dike along which occurs the garnet-epidote contact rock carrying some chalcopyrite. This deposit is interesting geologically, but the amount of ore exposed is small.

KARTA BAY.

GENERAL DESCRIPTION.

The name Karta Bay is applied as a general term to the entire northwest extension of Kasaan Bay. It is a relatively shallow embayment 3 miles in width, including a number of low, wooded islands and shoals, and affording several good anchorages. On the charts, however, the name is applied only to the harbor on the west side of this embayment, on which the Baronovich fishery and a small Indian village are located. The land northwest of this bay is low and is occupied by a "salt chuck" 2 miles in length and by 3 small lakes. To the southwest is a mountain range including Granite Mountain and other rounded summits less than 4,000 feet in elevation, and to the northeast is a low ridge of hills forming the divide between Karta and Thorne bays. The principal mines in the immediate vicinity are the Rush & Brown mine and the Venus group to the northwest, and the Goodro claims to the northeast (fig. 4). In 1901, when A. H. Brooks visited this section, none of these properties had been located, and not until 1904 were the copper-bearing ore bodies discovered.

The area is occupied principally by stratified rocks ranging from a fine tuff to a coarse conglomerate often showing a development of large hornblende crystals. These bedded rocks are invaded by granodiorite masses, and dike rocks of various composition intrude both the granodiorite and the bedded rocks. The copper ore occurs (1) at the contacts of the granodiorite with greenstone tuff, conglomerate, and limestone, as at the Rush & Brown mine; (2) along shear zones in the greenstone tuffs and conglomerates, as at the Venus group and Rush & Brown mine; and (3) in small masses and disseminated particles scattered irregularly through an altered basic diorite, as at the Goodro claims.

RUSH & BROWN MINE.

Situation and development.—The Rush & Brown property includes eight claims extending from "salt chuck" northwesterly, the principal mine workings being located on the Iron Cliff claim at an elevation of 300 feet, and about 2 miles from the wharf at the head of the bay (figs. 4 and 5). In 1904 this property was prospected by long trenches and open cuts, and a shaft 25 feet deep was sunk on

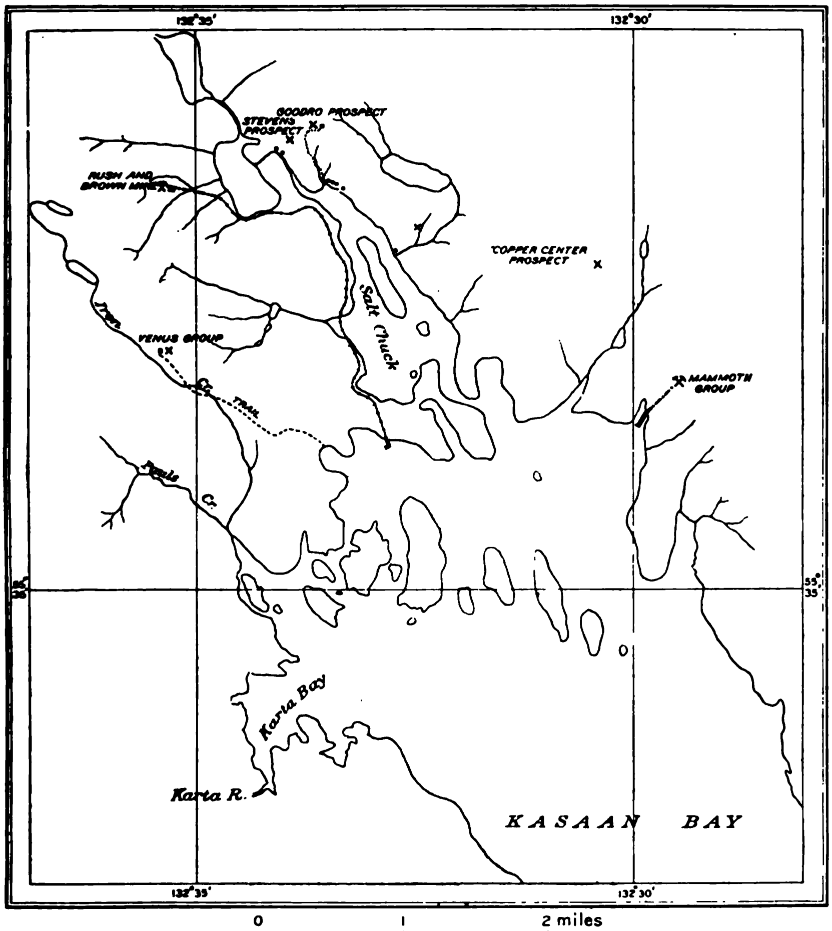

FIG. 4.—Map showing mines and prospects adjacent to Karta Bay.

the ore body. In 1905 it was leased by the Alaska Copper Company, and a new shaft was started 120 feet south of the old shaft and sunk to a depth of 100 feet. From the bottom of this shaft the principal ore body, the magnetite deposit, was developed by drifts and crosscuts and a drift was extended to a second ore body, the sulphide deposit, 160 feet farther northeast. At the close of 1907 the greater

portion of these ore bodies had been stoped out and the shaft sunk an additional 100 feet to a point from which a 200-foot level was started. The ore from the mines is transported by a gravity tram

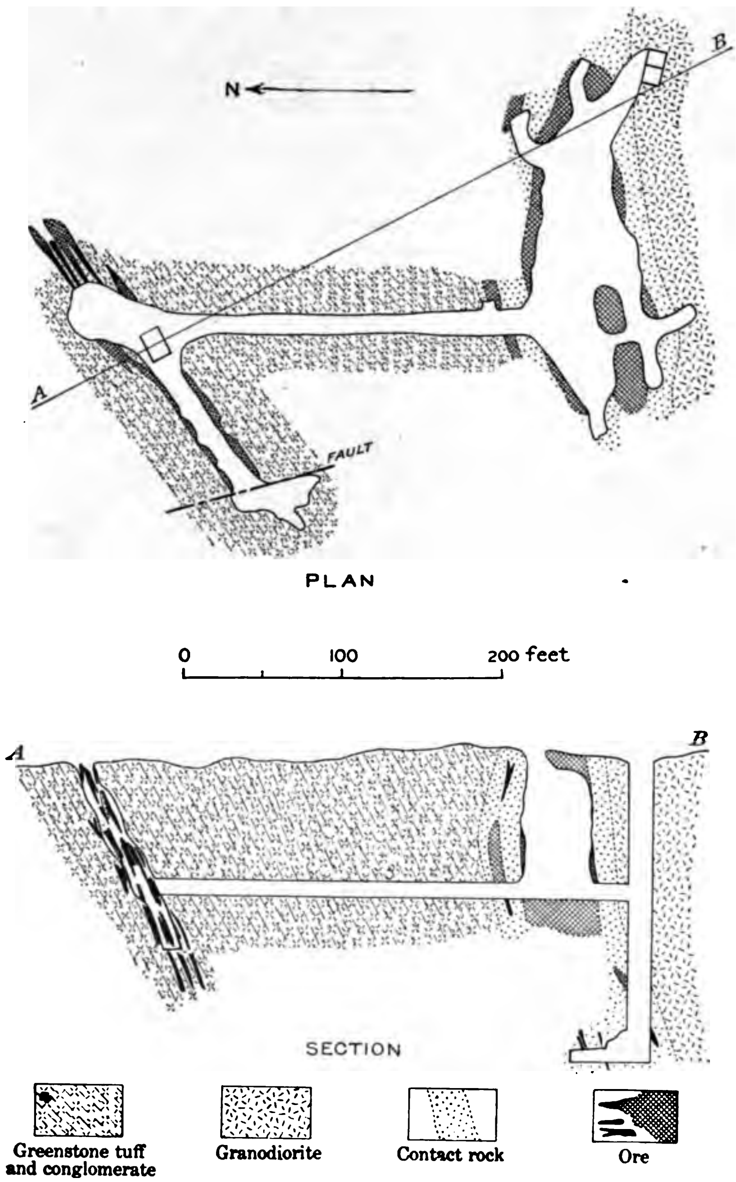

FIG. 5.—Sketch plan and section of mine workings, showing ore bodies at Rush & Brown mine.

to ore bunkers one-fourth mile below the mine and thence by a railroad 2¾ miles long to the wharf at the head of the bay, where ore bunkers of 2,000 tons capacity have been built. During 1906 ore

was shipped to the smelter at Coppermount, and in 1907 shipments were made to the Tyee smelter at Ladysmith, British Columbia.

Ore bodies.—Two ore bodies have been developed at the Rush & Brown mine. One is a contact metamorphic deposit consisting of a copper-bearing magnetite body 100 feet long by 30 feet wide in a garnet-epidote-calcite gangue lying between granodiorite and an indurated greenstone tuff, the line of contact striking nearly east-west. The other deposit, 160 feet to the north, occupies a shear zone in the greenstone tuff and conglomerate beds, and is a sulphide body composed of pyrite and chalcopyrite in a quartz-calcite gangue, which is 4 to 8 feet in width and has been developed over a length of 85 feet. The strike of this sulphide deposit is northeastward and its dip 60° SE. toward the larger deposit.

VENUS GROUP.

The Venus group of claims is located on Iron Creek 1¼ miles from the head of Karta Bay and about 1 mile south of the Rush & Brown mine (fig. 4). This property was located in 1904 and a magnetic survey made. Within the area of maximum attraction a pit was sunk and a trench 50 feet in length was made through the overlying débris, exposing the magnetic deposit. Below these surface excavations, which are at an elevation of 250 feet, a tunnel 75 feet in length has been driven which crosscuts 50 feet of débris and 25 feet of country rock, and at its face exposes ore. The country rock is an indurated greenstone tuff with interstratified quartzite beds, the ore occupying a shear zone. Associated with the ore is considerable sphalerite and pyrrhotite with quartz and calcite as gangue minerals.

GOODRO CLAIMS.

The Goodro claims, also known as the Joker group, are located one-half mile from the head of the "salt chuck" entering Karta Bay (fig. 4). The surrounding area is relatively low, the claims being located on a knoll about 400 feet in elevation. The copper deposit at this locality is of special interest because bornite is the dominant ore and it is the only locality in southeastern Alaska where bornite has been found in quantity. This ore occurs in small masses and disseminated particles associated with epidote, feldspar, and biotite, and is inclosed in a basic diorite which is largely replaced by these minerals. Native gold and considerable chalcopyrite also occur with the ore, and near the surface small amounts of chalcocite and native copper were noted. The diorite forms an extensive belt half a mile wide striking in a northwesterly direction (see Pl. I). Laterally this mineralization is exposed across a width of 60 feet and for about 100 feet in length. It has been developed by a surface

pit 12 feet deep, by a cut 70 feet long, and by a tunnel 125 feet long which crosscuts the ore-bearing mass 90 feet below the surface and 90 feet from its mouth. Slipping planes were observed at several points, but do not appear to have caused any noteworthy displacements. In an open cut a diabase dike is exposed which is evidently later than the ore deposition. Early in 1907 an ore shipment was made to the Hadley smelter and is reported to have yielded good values in both copper and gold.

TOLSTOI BAY.

GENERAL DESCRIPTION.

On the north end of Kasaan Peninsula, adjacent to Tolstoi Bay, which forms a good anchorage to the west, considerable prospecting has been done and numerous locations have been made, but none of the properties have been developed beyond the prospecting stage. The small promontory here is composed largely of the granodiorite intrusive masses which are exposed at Tolstoi Point and along the eastern slope of the mountain. On the western slope and along the east shore of Tolstoi Bay the rock exposures are principally of tuffaceous sandstone and conglomerate and occasional strata of limestone. Both the stratified and the intrusive rock masses are crosscut by dikes of porphyry and diabase (see Pl. I). The ore bodies are contact metamorphic deposits similar in character to those shown at the mines on the southern part of the peninsula. They are lenticular masses of magnetite carrying chalcopyrite and associated with garnet, epidote, calcite, and quartz, and inclosed in the bedded rocks near the intrusive granodiorite contact.

IRON CAP GROUP.

This property, also known as the Mahoney group, consists of two claims located on the northwest slope of Tolstoi Mountain at an altitude of 1,000 feet and is reached by a trail 1½ miles long starting from a cove 2 miles southwest of Tolstoi Point (fig. 1). In 1901 this property was prospected to a considerable extent by open cuts along a gulch and by several hundred feet of diamond-drill holes, but since that time it has been idle. The country rock consists principally of tuffaceous greenstone intruded by syenitic dikes of considerable width which are apparently related to the ore deposits. Three ore bodies have thus far been located, the largest being 20 feet in width and traceable for 50 feet in length, the major axis striking N. 45° W. A second ore body, separated from the first by a 30-foot dike of an altered intrusive syenite, is 12 feet in width and is limited on the foot-wall side to the southwest by a fault plane showing a considerable gouge seam, and toward the hanging wall grades into a garnet-epidote contact rock. The third ore body, which lies just

above the other two at an elevation of 1,080 feet, appears to be a flat-lying magnetite deposit only a few feet in thickness.

WALLACE GROUP.

The Wallace group includes four claims situated on the southeast slope of Tolstoi Mountain between 800 and 1,600 feet in elevation (fig. 1). At several points on this property small scattered masses of copper ore are exposed, but at no place have investigations been sufficient to determine the extent of these deposits. The uppermost ore exposures have been opened by a short tunnel in which a vein of garnet-epidote rock is shown containing chalcopyrite and striking N. 15° W. and dipping 20° SW. At the lower openings a magnetite-chalcopyrite ore is exposed, but the bodies do not appear to be extensive.

TOLSTOI GROUP.

The Tolstoi group of claims is located south of the Wallace group, just below the summit of Tolstoi Mountain (fig. 1). The ore bodies are low-grade magnetite-chalcopyrite masses similar to those on the Iron Cap group, but they have not been so extensively prospected. No developments more than the required annual assessment work have been accomplished on this property.

BIG FIVE CLAIM.

The Big Five claim lies half a mile east of Tolstoi Bay, on the trail to the Iron Cap group, at an elevation of 370 feet (fig. 1). A tunnel 50 feet in length and a shaft expose scattered masses of chalcopyrite, pyrrhotite, and pyrite in a gangue of garnet, epidote, and calcite, the deposit being 10 feet wide. This deposit is a replacement in limestone beds, and many slipping planes, defined by gouge seams, traverse both ore body and country rock. Assessment work only is done on this claim each year.

KASAAN BAY PROSPECTS.

SUNNY DAY GROUP.

The Sunny Day group of three claims is located on the south side of Kasaan Bay, opposite Kasaan village. The vein follows the hanging wall of a wide porphyry dike striking N. 65° E., with vertical dip, and carries chalcopyrite with low gold and silver values. It has been traced for some distance by means of surface exposures and open trenches and found to vary not only in width but also in mineralization. The porphyry dike invades a complex of highly metamorphosed greenstones, with occasional marble bands and bosses of diorite. A tunnel begun several hundred paces from the shore has been driven 150 feet to undercut the vein, but so far has failed to do so.

SHELTON GROUP.

This group of two claims is situated on the east side of Twelvemile Arm about 3 miles south of Hollis and at an elevation of about 1,000 feet. The vein outcrops in the beds of a small mountain creek and has been further investigated by a short tunnel and an inclined shaft 25 feet deep. The vein strikes N. 20° E., dips 65° SE., and occurs in a fractured limestone belt, which is an integral part of a formation including chlorite and greenstone schist and phyllites. In the tunnel well-marked slipping planes lined with gouge and slickensided were observed. This vein, which averages perhaps 6 feet in thickness, contains pyrite, chalcopyrite, and malachite in a quartz-calcite gangue, and is reported to carry values of copper with some gold and silver. Before actual mining can begin at this point, however, the vein must be exploited further and its probable extent determined.

NIBLACK ANCHORAGE.

GENERAL DESCRIPTION.

Niblack Anchorage is a small embayment and harbor 2 miles in length on the east side of Prince of Wales Island; its entrance, which is but 100 yards wide, connects with Moira Sound. The topographic relief in the vicinity is abrupt, the mountains rising to altitudes between 1,500 and 2,000 feet within a mile of tide water. A broad valley extends northwestward from the head of the bay and is occupied by two small lakes, the lower, Myrtle Lake, being three-fourths of a mile long and 90 feet above sea level, and from this fall sufficient power for mine purposes can be obtained (fig. 6).

The rock exposures in the vicinity of Niblack Anchorage consist of various types of greenstone schist with occasional bands of quartzite, altered grits, and quartz-sericite schist. They have a general N. 60° W. strike and dip from 60° to 70° SW. In places slickensided surfaces and gouge seams were noted, showing evidence of considerable faulting at various angles to the lines of bedding. The only intrusive rocks in the vicinity of the ore bodies that intersect these bedded rocks are occasional dikes of diabase. On the ridge north of Niblack Anchorage and also to the south in Moira Sound (see Pl. I) a granitic intrusive was exposed.

Pyrite and occasional particles of chalcopyrite are distributed widely throughout this rock complex, but the sulphide minerals are rarely present in amounts sufficient to warrant exploration. A zone of such mineral concentration occurs at the Niblack mine and has been developed across a width of 250 feet, its trend being northwest up the mountain slope.

The ore bodies in this zone occur as mineralized bands, veins, and lenticular masses, usually parallel to the rock cleavage, which is also the bedding plane. The bodies which are of most importance consist essentially of a massive sulphide ore, and vary from 10 to 100 feet in length and from 5 to 20 feet in width, and extend from 50 to 100 feet in depth. Many faults are present and have important bearing on the shape and extent of the ore bodies. The ore minerals are principally chalcopyrite and pyrite, with small amounts of sphalerite,

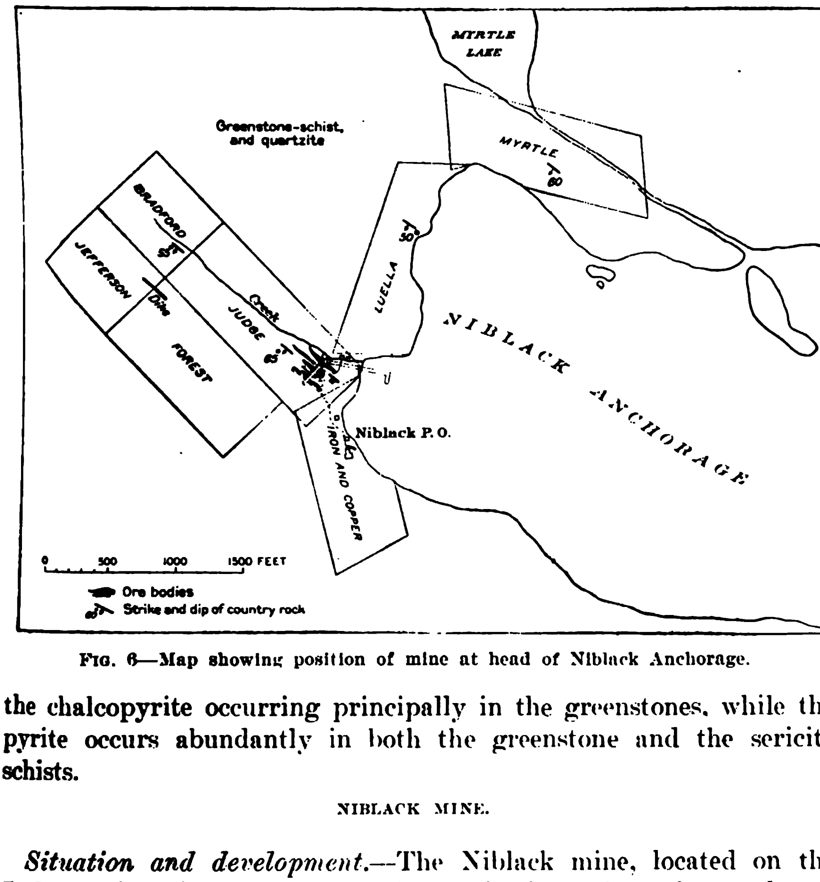

FIG. 6—Map showing position of mine at head of Niblack Anchorage.

the chalcopyrite occurring principally in the greenstones, while the pyrite occurs abundantly in both the greenstone and the sericite schists.

NIBLACK MINE.

Situation and development.—The Niblack mine, located on the Judge claim of Lookout group No. 2, is situated on the southwest side of the anchorage and but a few hundred feet from tide water. This property was first developed in 1902–3 by the Wakefield Mineral Lands Company and in 1904 was leased by the Niblack Copper Company, the present operators. The principal mine workings are on the Judge claim close to tide water, where the copper ore was first discovered (fig. 6). At a point 150 feet from and 30 feet above high tide is a two-compartment shaft inclined at an angle of 68°. From

this shaft four levels have been extended at depths of 50, 100, 150, and 225 feet from the surface, and during 1907 the shaft was extended an additional 75 feet in depth, from which point the fifth level was opened up. The total amount of underground drifting, including raises and winzes at the close of 1907, is estimated at about 5,500 feet.

The surface developments consist of a shaft house equipped with a 500-foot steam hoist, a 5-drill air compressor, a wharf 700 feet long extending to deep water, on which ore bunkers have been erected, a power house, a machine shop, a general store, and various other necessary mine buildings.

Ore bodies.—Three large ore bodies have been opened in this mine, besides smaller veins and masses occurring in the shaft and along the drifts. The north or foot-wall vein, which has yielded a large tonnage of the ore, is 200 feet in length, and averages 20 feet in width, and about 100 feet in depth, having the shape of a drawn-out lens. It extends from the surface to the 100-foot level, is parallel in strike and dip to the greenstone-schist inclosing rock, and pitches northwesterly. It is displaced in depth by fault planes crossing the rock formation at an acute angle and marked by a gouge 2 to 6 inches wide. Where the surface of this fault plane was observed in the stopes its face was grooved and polished. Other slipping planes occur at angles to this main fault and one apparently cuts off the ore body in the face of the northwest drift on the 50-foot level. The south vein, which has been developed principally from the 150-foot level, is similar in character, but not so large. In this, as was also noted in the other deposits, the sulphides of iron and copper appear to have replaced the greenstone inclosing rock to considerable extent, and fragments of the altered greenstone are present in the ore mass. These rock fragments are impregnated with the sulphides and often appear to grade into the massive ore without definite dividing lines. On the 225-foot level a newly discovered ore body has been exposed over a length of 90 feet and width of 15 feet. This body was intersected by an altered diabase dike apparently more recent than the ore deposition. The shaft is being sunk lower in order to investigate this ore body. The smaller ore bodies consist of veinlets a few inches wide, cutting the greenstone in various directions, and seams of sulphide ore in the more schistose rock following the stratification. In the country rock a decided penciling or slight folding occurs in the more schistose beds, forming grooves pitching 50° NW., along the lines which the ore bodies seem to follow.

The ore minerals are chalcopyrite and pyrite with small amounts of sphalerite and hematite and with some galena, the gangue minerals being quartz and calcite. Besides the copper content, gold and silver,

amounting to \$1.50 to \$2.50 per ton, and 1 to 2 per cent of zinc are present in the ore. The ores also contain considerable iron and sulphur and sufficient silica for smelting purposes.

LOOKOUT GROUP.

The Lookout group of five claims, belonging to the Wakefield Mineral Land Company, is situated on the south slope of Niblack Anchorage between 1,000 feet and 2,000 feet elevation and about 1 mile from tide water (fig. 6). These claims were first located in 1900, and in 1901 considerable development work was done and the adjacent areas were prospected. No important discoveries, however, were made and only a small amount of assessment work has since been done. The principal developments are on the Conundrum claim, where a 160-foot tunnel has been driven along a belt of mineralized schist striking N. 65° W. and dipping 70° SW. Along the hanging-wall side of this belt is a schistose greenstone, containing stringers of mineral-bearing quartz. A second tunnel 60 feet in length has been started on the same belt 150 feet above the lower tunnel. On the Lookout claims at 1,600 feet elevation an open cut exposes a mineralized belt of considerable width, consisting of brecciated sericite and greenstone schist intermixed with quartz and small masses of sulphides which also penetrate the schists. These mineralized belts are low in grade and at present can not be mined with profit. The introduction of a concentration plant to obtain a richer product for shipment is under consideration.

COPPER CLIFF MINE.

The Copper Cliff mine, also known as the Dama group, is located on the south side of Niblack Anchorage about 1 mile southeast of the Niblack mine (fig. 6). A large amount of development work was done on these claims in 1903–4 and to some extent in 1905, but since then the property has been idle. The main workings are on the Dama claim at an elevation of 750 feet and consist of a tunnel 200 feet in length, from which 250 feet of crosscuts and drifts have been extended, and a shaft 40 feet in depth sunk at a point 200 feet above the tunnel. In this tunnel the mineralized greenstone schists are exposed, including lenticular bodies of massive sulphide ore. The latter, however, are smaller and contain less of the chalcopyrite ore than the ore bodies at the Niblack mine. The inclosing country rock strikes N. 50° W. and dips 50° to 70° SW. with a prominent jointing system striking N. 45° E. and dipping 70° SE., and along these planes thin leaves or films of native copper were observed. On the adjoining claims mineralized schist is exposed by open cuts on trenches, but at none of these places were ore bodies of any size observed.

WAKEFIELD GROUP.

The Wakefield group of claims, property of the Moira Copper Company, lies about 2 miles northeast of Niblack at an elevation of 1,100 feet, on the east side of Luella Lake, and can be reached by trail either from Niblack Anchorage or from the north shore of Moira Sound (fig. 7). From the head of Niblack Anchorage the trail leads over a pass 1,850 feet in elevation and then down to Luella Lake 1,000 feet above sea level. The claims were located in 1904 and have not yet been thoroughly exploited. A shaft 50 feet deep has been sunk exposing an ore body for 25 feet in depth, and several open cuts have been made on a mineralized belt of schist. The country rock is made up of various types of greenstone schist and altered slates and grits, striking N. 40° W. and dipping 80° SW. The ore body is a lenticular mass of chalcopyrite 10 feet in width, its length and depth being undetermined. The mineralized belt of schist is about 60 feet across and contains a large amount of pyrite associated with quartz and epidote.

NORTH ARM OF MOIRA SOUND.

GENERAL DESCRIPTION.

The entrance to North Arm in Moira Sound lies just north of Niblack Anchorage on the east coast of Prince of Wales Island (fig. 7). It is an inlet 7 miles in length with a northwesterly trend and at its head is a narrow channel terminating in a "salt chuck" or shallow embayment. Just north of the narrow channel a stream 50 feet wide tributary from Mineral Lake enters the bay, and along this stream are the principal mine workings. The rock exposures in this inlet include the various types of greenstone and sericite schists interstratified by beds of limestone usually altered to a banded siliceous marble. At one locality an attempt has been made to quarry one of these marble deposits, but so far with little success.[a]

CYMRU MINE.

Situation and development.—The Cymru mine is located on the north side of Mineral Creek three-fourths of a mile from the head of North Arm (fig. 7). The ore occurrence at this locality has been known since 1900 and is briefly described by Alfred H. Brooks, who visited this section in 1901. Since that time the claims have been relocated at different times because of a lack of assessment work. Early in 1906 these properties were purchased by the Cymru Mining Company and active developments were begun and considerable ore produced the same year. Mining operations continued until

[a] A description of these marble deposits is given under the heading "Building stones," pp. 191–200.

June, 1907, when all work was suspended. The present developments consist of a shaft 105 feet deep, from which two levels at 50 and 100 feet have been extended, the 50-foot level connecting with an adit tunnel 184 feet in length. On the surface the veins have been opened to a considerable depth by trenches 4 to 8 feet in width and several hundred feet in length. At a point 350 feet to the west of the shaft an inclined shaft has been sunk 85 feet deep on the same vein. This shaft also connects with an adit level 30 feet in depth, which is 90

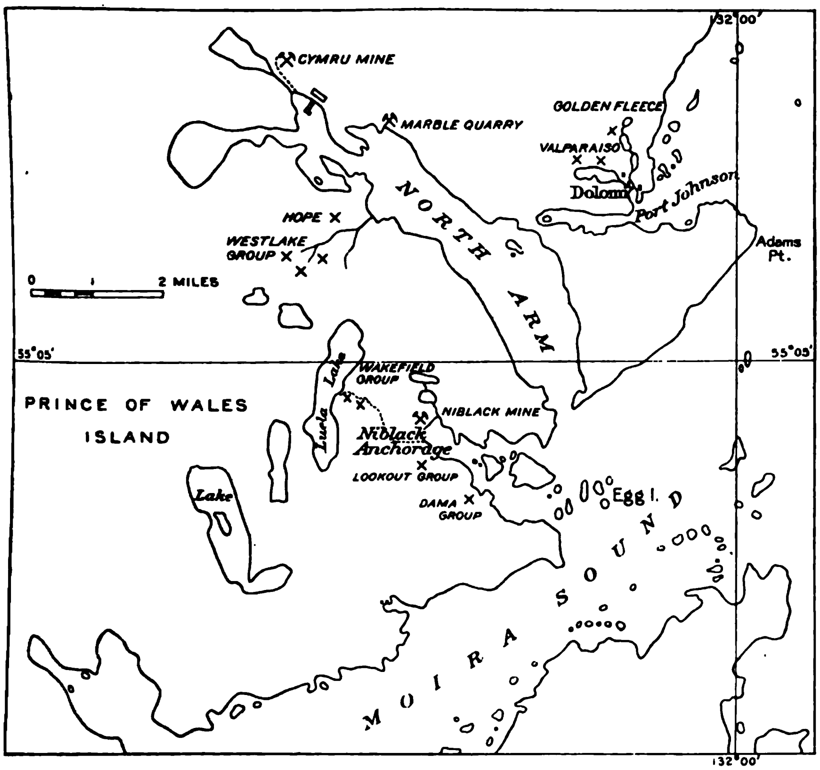

FIG. 7.—Sketch map of Moira Sound, showing location of mines and prospects.

feet in length. A surface tram of 36-inch gage leads from the mine to the ore bunkers at tide water, a distance of 4,200 feet, the cars being propelled by an 8-horsepower gasoline engine. From the ore bunkers, which have a capacity of 1,600 tons, a wharf 40 by 70 feet has been extended to deep water so that ore ships may be loaded directly from the bunkers by conveyor belts.

Ore bodies.—The ore bodies are vein deposits from 1 foot to 10 feet in width, inclosed in a limestone country rock striking N. 60° W. and dipping 65° SW. The limestone is interstratified with quartzite and greenstone schists and in many places is banded and altered to

marble. In these beds faulting planes occur, showing small displacements and shear zones. Four veins parallel with the stratification of the inclosing rocks have been exposed by surface trenches all within a distance of 100 feet of one another. The ore contained in these veins consists of pyrite and chalcopyrite in a gangue of quartz and calcite. Small transverse veinlets also occur in the wall rock adjacent to the veins, in which small ore masses are present, and the rock itself is at many places impregnated by the sulphide minerals. Surface oxidation or weathering along the vein outcrops has produced secondary ores, essentially malachite and limonite, but these are practically absent in the underground workings.

SKOWL ARM.

GENERAL DESCRIPTION.

Skowl Arm, an inlet 12 miles in length, has its entrance due west from the south end of Kasaan Peninsula, and 4 miles inland is the mouth of McKenzie Inlet, the south branch of Skowl Arm (fig. 8). The head of Skowl Arm is only 6 miles from Cholmondeley Sound, but the intervening land rises to a high elevation. The shores of this arm are abrupt and the surrounding mountains rise to altitudes of 3,000 feet or more. The channel itself is free from dangers to a point 1 mile beyond the mouth of McKenzie Inlet. Beyond this point and also in McKenzie Inlet are many reefs and rocky islands, rendering navigation dangerous.

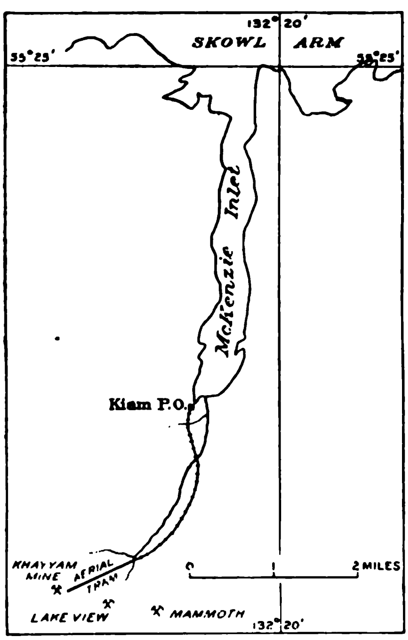

FIG. 8.—Sketch map of McKenzie Inlet, showing mine locations.

The rock exposures around the shores of this inlet are composed largely of a complex of dioritic and granitic intrusives which invade the older limestone and greenstone-schist strata exposed along the north shore of the inlet and to the south in Cholmondeley Sound. Within this area of igneous rocks are included belts of schist, gneiss, and shear zones, and it is in these that the ore bodies are found. The principal ore deposits at the head of McKenzie Inlet consist of masses and heavily mineralized portions of the schists containing essentially pyrite with chalcopyrite.

KHAYYAM MINE.

Situation and development.—The Khayyam mine, operated by the Omar Mining Company, is situated 2,500 feet above sea level on the summit of a mountain ridge 2.8 miles in an air line southwest of Kiam, a mining camp on McKenzie Inlet (fig. 8). This property was first located in 1899, and from 1901 to 1905 mine developments on a considerable scale were accomplished and transportation facilities were extended to tide water. In 1906 operations were suspended, but in July, 1907, were again resumed, and were in progress until October. The mine workings consist of several long tunnels 60 to 680 feet in length at elevations of 2,000 to 2,500 feet above tide water. From these workings an aerial tram 1 mile in length carries the ore to bunkers in the valley bottom, whence it is transported over a surface tram 2½ miles long to ore bunkers at tide water, where it is loaded into boats and shipped to the smelter.

Ore bodies.—In general the ore bodies are elongated lenses of sulphide ore coinciding in strike and dip with the schistosity of the inclosing rock. The surrounding formations vary greatly and consist chiefly of banded basic hornblende gneiss (altered diorite) interbanded with more siliceous gneiss belts, the trend of the structure being N. 85° W. and the dip 80° to 90° north. Several diabase dikes were noted intruding this complex of altered igneous rocks, and one dike 30 feet in width striking N. 65° W. at a slight angle to the schistosity can be traced nearly a mile. These dikes are of relatively recent intrusion and have played no part in the formation of the ore bodies. Two systems of joint planes are present along which faulting has occurred. The one system strikes N. 80° E. and dips 80° S. with an almost horizontal pitch indicated by striæ and grooves along the fault planes. The second system strikes north and south, dips 60° to 80° E., and pitches 60° to 70° N. At one point a fault of this system limits the ore body and is defined by gouge and broken rock. Many quartz veinlets are present along this transverse system of jointing cracks. The ore bodies are probably genetically related to the diorite, and particles of the sulphide minerals are finely disseminated throughout this rock where massive and less altered. The contacts of the ore masses are usually well defined, but in some places the ore is "frozen" to the walls.

The ore bodies have been exposed on the surface by open pits and trenches and have been crosscut at a depth of 50 feet by the Powell tunnel 220 feet in length. In this tunnel four ore bodies varying from 6 to 20 feet in width, along which 350 feet of drifting has been extended, are exposed. These ore bodies are all limited on the west by a fault plane, the displacement of which is not known. The Kimball adit tunnel, 350 feet lower than the Powell tunnel and 680

feet in length, crosses the formation so as to intercept all of the ore bodies exposed above it, but encounters no mineral bodies, and exposes only the banded and jointed diorite in which sulphides or iron in scattered particles occur locally. From the observations in the tunnels and surface openings the ore bodies appear to have the form of irregular elongated lenses nearly vertical in position, with the

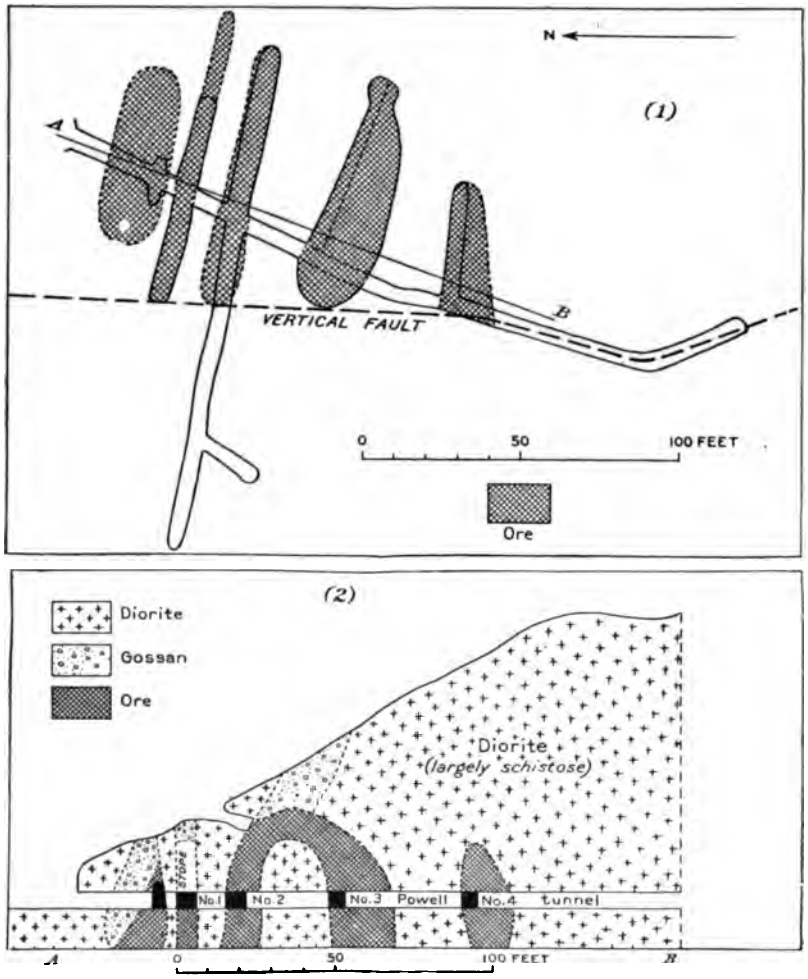

FIG. 9.—Plan and cross section of Khayyam mine workings, showing positions of ore bodies.

major axis parallel with the schistosity of the inclosing rock (see fig. 9). The main ore zone has been traced for 500 feet or more in length and is about 50 feet wide. Transverse faulting has displaced these bodies considerably at some points. The mineral content of these irregular deposits is chiefly pyrite with disseminated chalcopyrite, a small percentage of pyrrhotite, and some sphalerite and

magnetite. A sample taken by H. W. Turner[a] from No. 4 lens in the Powell adit was pulverized and treated with a horseshoe magnet and yielded 7 per cent of magnetitic pyrite or pyrrhotite. From the remaining sulphide the chalcopyrite was separated and each of the three sulphide minerals was then assayed to ascertain whether the precious metals accompanied a particular sulphide. The following results were obtained:

Analysis of sulphides from Khayyam mine, Skowl Arm, for gold, silver, and copper.

	Gold.	Silver.	Copper.
	Per cent.	Per cent.	Per cent.
Chalcopyrite	0.16	3.60	29.97
Pyrrhotite	.03	.62	2.67
Pyrite	.03	.40	2.32

The copper content of the pyrrhotite and pyrite is attributed to finely disseminated chalcopyrite in them, and the higher content of precious metals in the chalcopyrite suggests that the gold and silver favor this sulphide. A qualitative test of the pyrrhotite ore was made for nickel, but none was found. The values in the ore are essentially in copper and gold, but the sulphur content is considerable, and through this constituent alone the ore may be of value.

MAMMOTH GROUP.

Location.—The Mammoth and Lake View claims are situated about 1 mile southeast of the Khayyam mine at 1,200 feet elevation, just above the head of the Khayyam surface tram (fig. 8). These prospects are along the same general line of strike and in the same rock formation as the Khayyam deposits, but the ore bodies exposed are lode deposits of fairly uniform width and continuous in extent. The mine developments on these properties consist of two long tunnels and several open cuts. During 1907 work was in progress from July to October.

Ore bodies.—The main workings are on a lode deposit some 20 feet wide and in this the richer ore is concentrated along the hanging wall across a width of 2 feet. The strike of the lode is N. 75° W. and dip 80° N., the inclosing rock being the metamorphic schists. The ore mass is composed of pyrite, pyrrhotite, chalcopyrite, some zinc blende, and magnetite, with quartz, calcite, and chlorite occurring sparingly as gangue minerals. The same vein has been exposed on both Mammoth No. 1 and No. 2 claims over a length of 1,000 feet and has been developed principally by two tunnels 180 and 165 feet in length, at elevations of 1,100 and 1,250 feet, respectively.

[a] Min. and Sci. Press, August 11, 1906.

Other ore masses and bands of mineralized schist have been found on these claims and investigated by surface stripping and open cuts.

GRAVINA ISLAND.

GENERAL DESCRIPTION.

Gravina Island, containing 102 square miles, is separated from Revillagigedo Island by Tongass Narrows and forms a comparatively low, heavily timbered mountain mass west of Ketchikan. The highest peaks are less than 3,000 feet altitude. Along the northeast and northwest shores of the island rocks of the slate-greenstone belt are exposed. These overlie a succession of older schists, limestones, and occasional conglomerate beds of Devonian and lower Carboniferous ages, which are exposed at Vallenar Bay and along the southeast and southwest shore of the island. Intruding these beds are large masses of diorite which form a considerable portion of the east and west mountain ridges. Intrusive dike rocks of various composition are also present, and on the south end of the island is an area of rhyolitic lava flows and tuffaceous beds (Pl. II).

The mineral deposits consist of ore bodies bearing both copper and gold and occurring in lodes and veins in irregular masses. Copper deposits are being developed in the vicinity of Dall Head and Seal Bay, on the south end of the island, and near Vallenar Bay, on the north end. The gold deposits are confined to the slate-greenstone rocks along the northeast side opposite Ketchikan.

PROSPECTS AT SEAL BAY AND DALL HEAD.

Considerable prospecting has been done on the southern end of Gravina Island, copper-bearing deposits having been discovered and exploited at several localities. The geology of the region is extremely intricate, owing to the great variety of intrusive and extrusive rocks and to the intricate faulting which has affected the entire rock complex. The general topography is rough and is controlled apparently in large measure by the bed-rock geology. The west side of Gravina Island is flanked by a range of hills which join north of Dall Bay with an abrupt ridge running parallel with the southeast shore. The latter ridge consists largely of red-colored porphyritic lavas and tuffs, frequently intercalated with calcareous deposits in which traces of fossils are visible. West of Dall Bay banded gneiss covers a large area, and still farther west in a small bay a fossiliferous limestone conglomerate of lower Carboniferous age was discovered, which contains abundant altered eruptives and is underlain to the south by eruptive rocks of various types. Along the shores of Seal Bay a similar conglomerate occurs, but it is less calcareous and without fossil remains. Near Seal Bay numerous large dikes of pegmatite

invade the schist, quartzites, and greenstones. The general strike of the schists is about north and the dip vertical or steep toward the east.

The ore bodies occur chiefly along planes of movement in the schists, especially along the planes of bedding and schistosity. In general, deposits are found sporadically and do not appear to persist for any distance along the surface. No ore bodies have yet been developed in depth in this area, and it is probable that their occurrence, both horizontally and vertically, is irregular. The ore is chiefly pyrite and chalcopyrite, carrying some gold, with quartz, calcite, chlorite, and iron carbonate as gangue. With the exception of one claim near Dall Head, the claims in this area have been developed very slightly during the last few years and have changed but little since 1901, when Brooks visited and reported on the principal claims. It will, therefore, be necessary here only to supplement his descriptions with the mention of the few changes that have occurred in the intervening years.

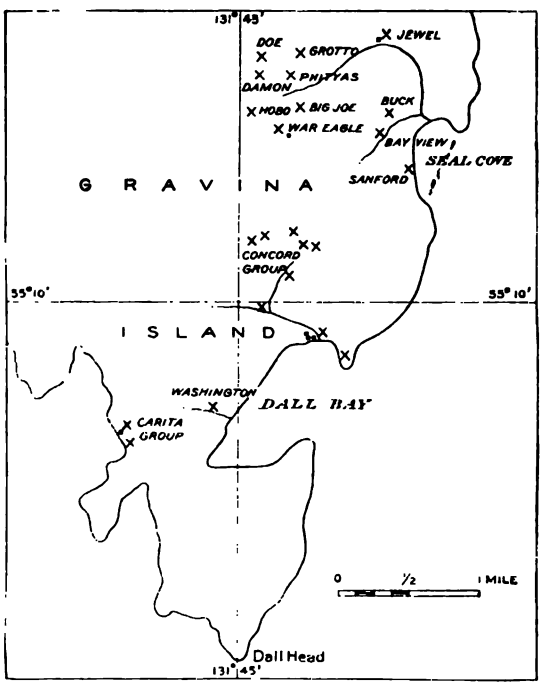

FIG. 10.—Sketch map of Seal Cove and Dall Head, showing locations of prospects.

On the Concord group near Dall Head a shaft has recently been sunk on a 3-foot vein striking N. 20° W. and dipping vertically in a country rock of metamorphosed breccia conglomerate (fig. 10). The metallic minerals are pyrite and chalcopyrite with quartz and carbonate gangue. Nearer the shore on the Sanford group a similar vein has been exposed by open cuts and a short shaft in a much-altered chlorite rock, but high values do not characterize these ore bodies. The claims visited by the writers were: The Jewel claim, on a quartz vein with pyrite striking north and south; the Doe claim on a quartz vein 3 to 6 feet wide, striking N. 20° E., containing pyrite and chalcopyrite, and inclosed in a siliceous chlorite schist; the Buck claim, on a wide quartz vein in altered quartzite and schist, which is reported to

assay well in gold and copper; the Damon and Plutyas claims, on a quartz vein heavily mineralized with pyrite and striking N. 20° W. in a banded chlorite country rock; the Bay View claim, on a quartz vein with pyrite and chalcopyrite, along which a 100-foot drift has been driven; the Grotto claim, on a wide vein deposit which has been developed by about 550 feet of drifts and crosscuts, and which occurs along slipping planes in a complex country rock consisting of chloritic schists, conglomerates, and altered eruptive masses; the Big Joe claim, on a well-defined 10-foot quartz vein striking north and south, which carries pyrite and some chalcopyrite and can be traced for over 3,000 feet in much metamorphosed chlorite schists; the Hobo and the War Eagle claims, on a 10-foot vein with well-defined walls containing pyrite and chalcopyrite; the Algonquin group of four claims and the Black Warrior group of three claims, on small veins of the usual type in chloritic schistose country rock; and the Carita group, located in a cove 1 mile west of Dall Bay, on a quartz vein in calcareous conglomerate carrying stringers of chalcopyrite (fig. 10).

PROSPECTS AT VALLENAR BAY.

During the early mine developments of the Ketchikan district in 1899 and 1900 much work was advanced on a group of claims at the head of and to the west of Vallenar Bay (Pl. II). Shafts were sunk and tunnels driven, but the ore bodies did not prove to be extensive, so that work was soon suspended and has not been resumed. At the Six Point property on the west side of the bay the shaft and tunnel expose a quartz vein apparently following the contact of a diabase dike and containing pyrite with some chalcopyrite, the inclosing country rock being a slaty limestone. The vein is but a few feet in width and pinches to a narrow seam in several places. Southwest of this property on the west coast of the island is the White Knight group of two claims, on which have been exposed small masses of chalcopyrite ore, associated with pyrrhotite and pyrite, inclosed in a greenstone country rock. Practically no work has been done on these mineral deposits and little is known of their extent and value.

DUNCAN CANAL.

GENERAL DESCRIPTION.

Duncan Canal is an inlet 20 miles long and three-fourths mile to 1½ miles wide, on the south side of Kupreanof Island, 3 miles west of Wrangell Straits. At the head of the bay is an extensive tide flat, which runs dry at low water and prevents navigation farther than 12 miles from the entrance. At high water, however, a small launch or rowboat can proceed to the head of the long arm, shown

on the map, and from this a low marshy valley extends northward across the island to Portage Bay, a distance of 5 miles (fig. 11).

The rock formations of this canal are made up essentially of slates and greenstones along the eastern shore and of calcareous and siliceous schists on the western shore. In the center of the canal is a small island composed of lava showing basaltic structure (Pl. III).

The mineral deposits are all located at the head of the bay and are reached by trails starting from the center arm. They consist of vein deposits either in the slates and greenstones or in the schists, which contain principally values in copper, with some gold and silver. None of the properties have been developed beyond the prospecting stage, and there has therefore been no production in this section.

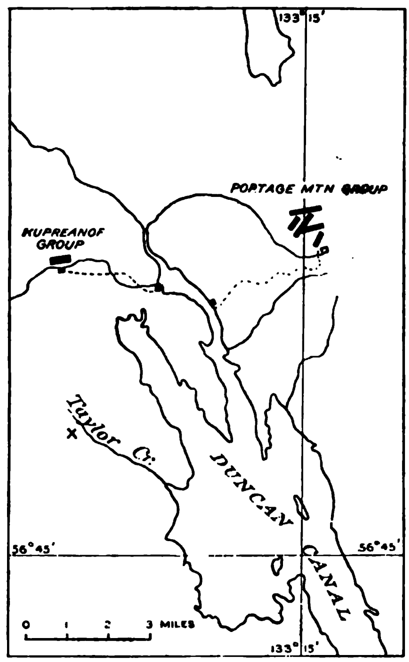

FIG. 11.—Map showing location of Portage Mountain and Kupreanof groups of claims and prospects at the head of Duncan Canal.

PORTAGE MOUNTAIN GROUP.

This group of claims, owned by the Portage Mountain Mining Company, is situated 4 miles from tide water at the head of Duncan Canal, at an elevation from 2,000 to 3,000 feet on the west slope of Portage Mountain (fig. 11). The rock formations on these properties consist of slates and greenstones intruded by diorite masses and dikes of diabase. The mineral bodies are vein deposits striking northeastward across the general northwest trend of the inclosing slates and greenstones. Several veins at various points have been located and prospected by small open cuts. They are but a few feet wide and contain some chalcopyrite and small values in gold and silver, the gangue being quartz and calcite. Although mineral-bearing veins are exposed at a dozen or more points, no large ore bodies have as yet been developed in this area.

KUPREANOF GROUP.

The Kupreanof group of claims, owned by the Portage Mountain Mining Company, lies 6 miles to the east of the Portage group. It is 2½ miles from the head of Duncan Canal and at an elevation of

800 feet (fig. 11). This group was first located in 1900 and was well prospected by tunnels and shafts, after which no work was done, and the claims were relocated in 1902. Since that time little more than the annual assessment work has been done. On this property a vein deposit 200 feet long and from 3 to 6 feet wide, having a northeasterly strike and dip of 30° N., into the mountain, is exposed at several points. The vein material is composed largely of sulphide minerals, pyrite and pyrrhotite predominating and containing chalcopyrite and small values in gold and silver. The gangue is quartz and calcite. A considerable quantity of ore of moderate grade has been developed at this locality, but the position of the deposit is not now favorable for economical mining.

TAYLOR CREEK PROSPECTS.

The prospects up Taylor Creek are located 1½ miles from West Bay at the head of Duncan Canal at an elevation of 170 feet (fig. 11). These locations were made in 1904, and small developments have since been made. An open cut 30 feet long on the west side of the creek, 100 yards above a cabin, exposes a 12-foot band of mineralized limestone intersected by quartz veinlets and containing galena, sphalerite, pyrite, and chalcopyrite in small, scattered patches. The strike of this deposit was N. 80° W. with a dip of 45° NE., parallel to the bedding planes of the inclosing rocks. Diabase dikes from 1 foot to 6 feet wide, striking northward, were observed in the creek bed intruding the rocks.

GOLD MINES.

GENERAL STATEMENT.

The gold mines of the Ketchikan and Wrangell districts are few and scattered, and only a small number of the many gold prospects and claims have been developed to the producing stage. Although this metal is widely distributed in all of the older rock formations, both in veins and lodes, it is rarely found in deposits of sufficient size and grade to constitute ore bodies, and those localities where the ore bodies are being mined are necessarily located but a short distance from tide water, where transportation facilities and water power are available. The ore produced by these mines is for the most part free-milling, that is, an ore from which the greater percentage of the gold content may be extracted by amalgamation. It is therefore most advantageously treated in a stamp mill by amalgamation and concentration, and the concentrates alone should be shipped to the smelter for treatment, though in certain instances where a siliceous ore is in demand the gold ore has been sold direct to the smelter. In general the vein ores contain the largest values per ton,

but the lode ores though lower in grade are present in greater quantity. Both types of deposit are being mined with profit.

THORNE ARM.

General description.—Thorne Arm is a wide, deep-water indentation in the southern end of Revillagigedo Island. Its general trend is about north and south across the strike of the underlying country rock. The dissected mountain ridges are less precipitous and lower than those to the east and rarely exceed 2,000 feet in elevation. Abundant evidence of intense ice abrasion characterizes the landscape on all sides. The shore line is abrupt and rocky and near the head of the bay should be approached in boats with caution because of hidden reefs and rocky shelves which extend far into the bay.

The bed-rock geology is complex and structurally intricate (Pl. II). At the upper end of Thorne Arm are crystalline schists and limestones, whereas toward the central part slates and greenstones intruded by large masses of altered basic igneous rocks predominate. The entire complex is further cut by later granitic and dioritic intrusive dikes and stocks similar in character to the Coast Range granodiorite. The southern third of the bay cuts across a wide intrusive belt of granodiorite, which in places contains garnet as an accessory constituent and is noteworthy because of its uniform composition and appearance and the absence of dikes which prevail along the western contact of the Coast Range intrusives. Dike rocks, ranging in composition from diabase to aplite and quartz porphyry, are also common. At the Sealevel mine a dike rock occurs in conjunction with the ore body and was described by Brooks [a] as an altered rhyolite (aporhyolite). It is interesting because of its probable bearing on the genesis of the ore. The latest rocks in the Thorne Arm region are postglacial basaltic lava flows, which occur as wide surficial sheets near the northwest head of the bay, also northeast of Sealevel and 5 miles to the south along the shore. These lava flows are of the usual feldspar basalt type with occasional crystals of olivine showing only slight alteration and are in many places vesicular and rough in appearance; columnar jointing characterizes many exposures. Although postglacial, these lavas are covered more or less completely with a dense forest growth.

Mineralization is widespread in this region, especially near the intrusive granite masses. Near Sealevel, where prospecting has been done most energetically, the values are contained in gold- and silver-bearing quartz veins included in the sericite and greenstone schists and usually following or crosscutting an intrusive dike rock. The veins trend in a general northeasterly direction and dip southeast at varia-

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[a] Brooks, A. H., Prof. Paper U. S. Geol. Survey No. 1, 1902, p. 65.

ble angles, frequently filling original slipping planes or fissures bounded by free walls with more or less gouge material.

The ore consists usually of the sulphides, pyrite, pyrrhotite, galena, and sphalerite in variable quantities, together with occasional particles of native gold. The gangue minerals are chiefly quartz and calcite with variable amounts of chlorite, muscovite, siderite, and perhaps feldspar. Considerable gold was extracted from the Sealevel vein several years ago, though in the last few years no work has been done.

The accompanying sketch map (fig. 12) was drawn largely from hastily paced traverses and presents only the general location of the more important claims. Many other claims were observed, but they have been developed so slightly and relocated so frequently that it was not possible in the short time available to unravel the latest location notices and to trace out the latest lines in the maze of interweaving lines of previous locations.

Sealevel mine.—The Sealevel property has been in litigation for several years, and developments have progressed very slowly in consequence. Conditions have changed but slightly since the visit of Alfred H. Brooks in 1901, and his descriptions apply equally well to present conditions. The claim is situated near the northeast head of Thorne Arm and has been developed underground by a 3-compartment shaft 125 feet deep with two drifts along the ore body at the 50- and 125-foot levels respectively, the total length of which with crosscuts is over 1,200 feet. A short tunnel with a winze has recently been driven on the vein at a point 350 feet N. 60° E. of the shaft house. The vein is exposed at several other points by open cuts and appears to continue into the adjoining Sea Breeze claim. The surface equipment is adequate and consists essentially of a rock house at an elevation of 250 feet, connected by an inclined tram with a 30-stamp mill at the beach. The power is furnished by a pipe line from Gokachin Falls, 1 mile distant. The stamp mill was in operation from July, 1901, to July, 1902, and considerable gold was recovered, but since that time it has been practically idle.

The country rock at this claim is composed of various types of schist, the greenstone and calc schists predominating and striking in general west of north with variable dips to the east. Folding is not uncommon and evidences of slipping are noticeable at many points. Dikes of blue altered porphyry crosscut the schists in a direction N. 60° E. with a dip 65° SE., and are in turn cut by the mineral-bearing quartz veins. Under the microscope the dike rock appears so highly altered that its original texture is obliterated to a large extent. Secondary quartz, muscovite, calcite, chlorite, and pyrite are present in abundance and indicate only by their general

grouping the outlines of the feldspars and colored silicates from which they have been derived. The original texture of the rock was porphyritic, with phenocrysts of quartz, plagioclase, and a colored

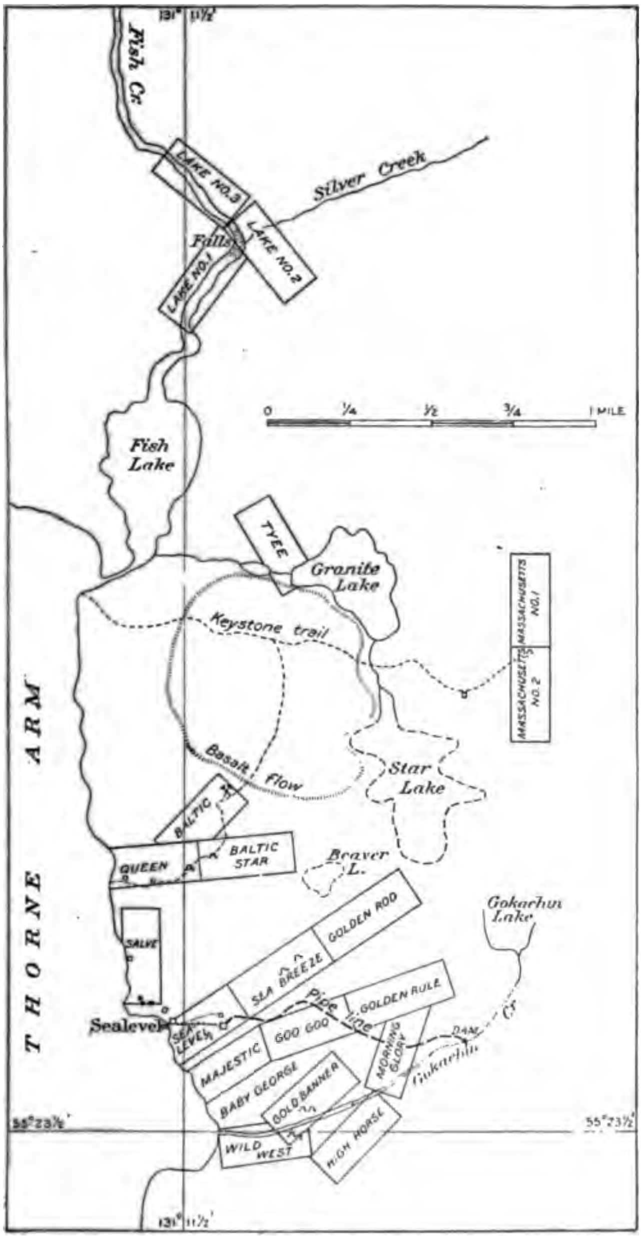

FIG. 12.—Map showing claim locations near Sealevel, at head of Thorne Arm.

silicate embedded in a fine matrix of similar composition. The general term porphyry applies to rocks of this type, although this particular rock is less siliceous than the usual porphyry. Included

within the quartz veins at the Sealevel mine are large fragments of this rock which are said to carry as high values in precious metals as the quartz veins carry. Cubes of pyrite occur frequently in all parts of the dike and the schistose country rock, but the values seem to be confined to the walls adjacent to the vein. Two parallel veins 15 feet apart have been followed by the underground workings, an easterly one 5 feet wide and a westerly one 1 to 2 feet wide. At the time of visit only the 50-foot level was accessible, the lower workings being filled with water. The two veins there exposed are well defined and show frequent evidence of minor faulting. Numerous offshoots and stringers branch from the main vein into the dike rock without change in general aspect. The course of the belt of quartz veins and mineralization crosscuts the 25-foot porphyry dike and passes into the adjacent greenstone schist. The degree of mineralization of the veins, however, appears much greater within the limits of the dike than in the adjacent schists. This belt has been traced by open cuts and prospect tunnels for about 2,000 feet and preserves its general character throughout that distance.

The ore consists essentially of pyrite, galena, and sphalerite, with occasional flakes of native gold and a gangue of quartz with some muscovite. The larger percentage of the gold content is said to be free milling, while the value of the concentrates recovered is reported to be moderate. The mine is favorably situated for the economical treatment of the ore.

Sea Breeze claim.—The Sea Breeze claim adjoins the Sealevel on the northeast and is located on the extension of its mineralized belt. The developments consist chiefly of two short tunnels and numerous open cuts which expose the vein for a long distance. The veins occur frequently in or near a wide porphyry dike, which invades the greenstone country rock under conditions similar to those at the Sealevel property. The quartz veins are, however, less regular and vary in width from 1 to 8 feet. Faulting and intense fracturing and rapid variation in mineralization are characteristic features of this vein. The ore consists of porphyry, galena, and sphalerite, with an occasional speck of native gold in the gangue of white quartz. The values in this vein are reported to be in general low with much variation in metal content within the vein, the content being apparently proportional to the amount of mineralization.

Golden Rod claim.—Although the Golden Rod claim adjoins the preceding claim on the northeast, it is located on a vein of different character outcropping in a different country rock. Several open cuts along the northern slope of a steep hill of granodiorite expose the quartz vein, which at a point 320 feet above sea level was 16 feet wide, with a strike N. 50° E. and a dip 80° SE. The granodiorite country rock is aplitic in character and often gneissoid in structure,

Mineralization is slight and the values are said to be correspondingly low.

Googoo claim.—The Googoo claim was located in 1905 on a western extension of the Golden Rod claim. At the point of discovery a quartz vein 22 feet wide has been developed by a shaft 20 feet deep. To the northeast, however, the vein is only 3 feet wide and has been developed by a tunnel 15 feet long. Free gold, pyrite, sphalerite, and some galena were noted in the vein on this claim, and pockets containing considerable free gold are reported to have been found.

Majestic claim.—The Majestic claim, originally known as the Mother Lode claim, adjoins the Googoo claim on the southwest. On this property a quartz vein 20 feet wide occurs inclosed in the altered schists. The strike of the vein is N. 63° E. and the dip 80° SE., and it may represent the continuation of the Googoo vein. Pyrite, sphalerite, and galena were noted in the quartz gangue. The developments consist of an open pit 10 feet deep and a tunnel 10 feet long near the center of the claim.

Golden Banner claim.—The Golden Banner claim, originally located as the Golden Tree claim, is located on Gokachin River about a mile from the beach. The principal developments on this property consist of a tunnel 60 feet in length. The country rock is composed of several types of schist, striking in general N. 15° W. and dipping 85° SW., intruded by a porphyry dike, which forms the hanging wall of the quartz vein at the shaft. The vein varies in width 1 foot to 6 feet and is faulted slightly at several points. At the shaft, which is situated on the crest of the ridge north of Gokachin River, the vein is 3 feet wide, and it can be traced over 150 paces from the shaft in a direction N. 65° E. with a dip 70° to 80° SE. The ore is made up of pyrite, galena, and sphalerite, with occasional particles of free gold, in a quartz gangue. The values, which are probably irregularly distributed, have not been actually determined.

Baby George claim.—The Baby George, which has received very little development, is located at the mouth of Gokachin River. A short prospect tunnel has been driven to expose the quartz vein, which is 10 feet wide and occurs in argillites and greenstone schist.

Wild West claim.—The Wild West claim, a relocation of the Tide Water claim, is situated on the south bank of Gokachin River near its mouth. The ore body consists of several quartz stringers about 1 foot wide, striking N. 60° E. and dipping 70° SE., and inclosed in banded argillites and sericite schists. The developments are slight and consist of surface cuts only.

High Horse claim.—The High Horse claim, a relocation of the Monster claim, lies east of the Wild West and has been developed by open cuts and a short prospect tunnel. The vein varies from 6 inches

to 3 feet in width, strikes N. 55° E. and dips 75° SE., and occurs in a complex of schists striking N. 50° W. and dipping 80° NE. The ore consists chiefly of pyrite with some sphalerite. Pyrite cubes are also abundant in the adjacent schists.

Salve claim.—The Salve claim is situated north of Sealevel and runs from Russel Point northerly parallel to the shore line. The vein is exposed by an open cut and test pit and is essentially a band of mineralized sericitic schist with few small stringers of quartz. The schists in the vicinity strike in general N. 20° W., dip 70° NE., and show folding and some faulting. Dikes of porphyry cut the schists in a northeasterly direction and at one point are apparently later than the quartz stringers. The ore is pyrite with low values in gold.

Queen and Baltic claims.—The Queen and Baltic claims are situated north of the Salve claim and are both located on a quartz vein which has been exposed by open cuts, two short prospect tunnels, and an inclined shaft 40 feet deep. The vein trends in general east and west, with a steep to vertical dip, and cuts across the cleavage of the inclosing schists, which strike N. 20° W. and dip 70° NE. The vein varies in width from 1 to 6 feet and consists of quartz with some pyrite, sphalerite, and low values in gold.

Baltic Star claim.—The Baltic Star lies north of the preceding claims and has been developed still less. The quartz vein is included in mineralized schist and trends N. 60° E. with a dip 75° SE. It is 1½ feet wide and has been traced for 300 feet in length. Pyrite, sphalerite, and galena with low free-gold values constitute the ore, with quartz as gangue.

Tyee claim.—The ore body of the Tyee claim near Granite Lake is noteworthy because it occurs wholly within a wide granite mass. The vein is 4 feet in width, strikes east-west, dips 78° S., and contains besides quartz small quantities of pyrite, sphalerite, and galena, with low values in gold.

Massachusetts claims Nos. 1 and 2.—The two adjoining Massachusetts claims, originally known as the Keystone claims, are situated northeast of Sealevel. The trail leading to the claims passes over a wide area of postglacial basaltic lava, elevated plateau-like above the surrounding country and remarkably level on top. At the claims a tunnel 80 feet in length and 500 feet in elevation has been driven; also a shaft has been sunk 30 feet on the vein, and a drift from the shaft 50 feet in length and several open cuts have been made. The country rock consists largely of schists with some interbedded greenstones striking north and south and dipping northeast at steep angles. On the dump from the shaft were fragments of granite probably derived from an intrusive dike exposed by the shaft, which at the time of visit was filled with water. At the surface the vein is 5

feet in width, but in depth it decreases to 6 inches and divides into small stringer veins. The ore consists of pyrite, galena, and sphalerite in a gangue of white quartz. The values in gold are said to be favorable near the surface.

Lake claims Nos. 1, 2, and 3.—These claims have recently been located on Fish Creek near the junction with Silver Creek and the Falls. They have not yet been developed to any extent and nothing definite is known as to their value. The country rock consists of micaceous and greenstone schists, invaded by a granite mass. The included quartz veins are similar in character and contain pyrite, galena, and sphalerite in small quantities. One quartz vein on Lake No. 2 and Lake No. 3 measures 60 feet in width at one point and runs N. 15° W., with vertical dip across the cleavage of the schists.

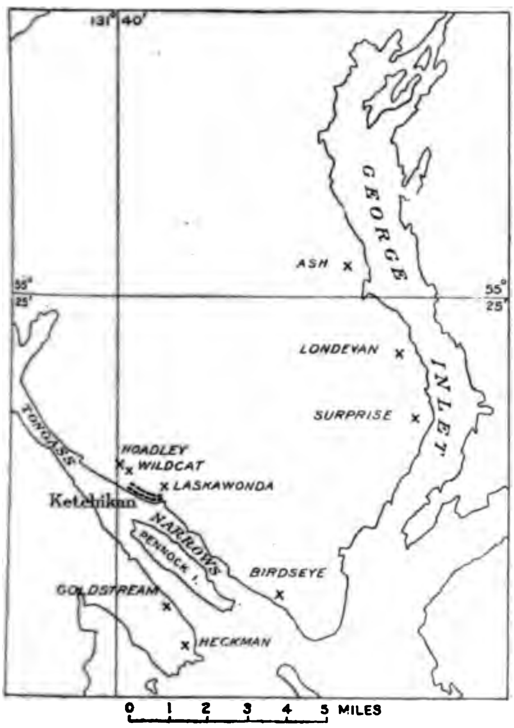

FIG. 13.—Sketch map showing location of prospects adjacent to George Inlet and Tongass Narrows.

GEORGE INLET.

General description.—George Inlet is one of the deep embayments on the southwest side of Revillagigedo Island having a length of nearly 18 miles and varying from three-fourths of a mile to 2 miles in width (see Pl. II and fig. 13). Starting at its entrance and following inland, the greenstones and argillaceous slates are first exposed for 2 miles along the north shore; a granite belt $2\frac{1}{2}$ miles wide is then crosscut and is followed by more argillaceous slates with occasional greenstone beds. Toward the head of the inlet the crystalline schists interstratified by belts of marble compose the shore exposures. The general strike varies from N. 10° to 50° W. and the dip usually steep to the southwest. The ore bodies so far discovered are all located on the northwest shore of the inlet from 5 to 10 miles from its entrance. These consist of both large and small vein deposits striking parallel and at angles to

the bedding plane of the schists. The principal values contained are in gold, which in some of the deposits is associated with galena sphalerite and pyrite in considerable amounts.

Peterson group.—This property of four claims is situated close to tide water on the northwest shore of George Inlet about 5 miles from the entrance and has been prospected by open cuts and two short tunnels. The principal vein deposit occurs along vertical slipping planes which parallel the rock structure in strike but intersect the beds in dip. The schist formation at this point strikes N. 35° W. and dips 50° SW. The vein varies greatly in width, averaging 15 feet, and is reported to have been traced for 1,000 feet along its trend, its walls being defined by gouge seams. The metallic minerals contained are pyrite, galena, zinc blende, pyrrhotite, in a gangue of quartz, calcite, and graphite. Well-defined gouge planes limit the deposit in many places. The values reported include both gold and silver. Other vein deposits have been exposed on this property, but still remain undeveloped.

Lon-de-Van group.—This property of eleven claims, originally called the Telegraph group, is located on the north side of George Inlet, 5 miles above the Peterson group. On this property six well-defined and persistent veins have been exploited by open cuts and tunnels at different points along their strike. The country rock consists largely of banded argillites and black slates with occasional acidic porphyry intrusives. Two sets of veins occur, an old transverse set filling cross-fracture cracks in the sedimentary complex, and in one instance attaining a remarkable thickness; and a second system filling planes of movement along the beds of the formation and striking usually N. 10° W. with variable dip, in general about 50° SW. Six veins of the second type have been discovered, one of which has been traced for several thousand feet in length. The veins vary from 1 to 4 feet in width and many of them are adjacent to intrusive porphyry dikes. The metallic minerals contained are pyrite, galena, and sphalerite, in a quartz and calcite gangue. Moderate values in gold and silver, the latter in some instances exceeding the gold content, are reported. Only a small percentage of the gold is free-milling, and it will be necessary to concentrate the ore to recover its values. The cross veins, one of which has a thickness of several hundred feet, carry lower values than the strike veins and but a small amount of pyrite, and are therefore still undeveloped. Openings have been made on these deposits at different points extending from tide water to a point a mile from the shore, at an elevation of 1,000 feet.

Ashe's group.—This group is located about 3 miles above the Lon-de-Van group near tide water at a small embayment on the north side of George Inlet. The vein deposit at this point follows a porphyry dike which in turn is parallel to the inclosing slates and schists, and

has been exploited by a short tunnel and several open cuts. The vein is about 2 feet wide, striking N. 75° W. and dipping 10° to 20° NE., though both strike and dip vary considerably at the different exposures. It contains abundant galena and sphalerite in a quartz-calcite gangue carrying small gold and silver values. The porphyry dike is also impregnated to a small extent with these minerals. The developments on this deposit include a 35-foot tunnel, a short shaft, and several open cuts.

TONGASS NARROWS.

General description.—Along the shores of the narrow body of water called Tongass Narrows, which separates Revillagigedo and Gravina islands, greenstone schists and black slates outcrop and trend in general parallel to the shore line (see Pl. II). On the Revillagigedo Island side of the narrows a number of claims have been located, but no ore bodies of importance have yet been developed. The ore bodies include both quartz veins and bedded deposits and frequently occur near intrusive porphyry and aplitic dikes. The mountains east of Tongass Narrows trend parallel to the coast and range from 2,000 to 3,000 feet in elevation. They are composed largely of granite, which intrudes the greenstones and slates. Several of the quartz veins near the contact of the intrusive masses with the sedimentaries are sporadically very rich in free gold, but the average content is low.

Hoadley group.—The Hoadley group includes five claims and is located about 2 miles north of Ketchikan and one-half mile from the beach (fig. 13). The developments consist chiefly of open cuts and short drift tunnels, besides an arrastre in which the free-milling ore is treated. The country rock consists of siliceous and argillaceous schists striking northwest and intruded by large granitoid dikes, usually parallel to the formation and ranging in composition from syenites to gabbros. The veins occur within these intrusives, vary from 4 to 24 inches in thickness, and are usually but a few hundred feet in length. There are two sets of veins, an older set containing chiefly pyrite and pyrrhotite and striking north and south with dip 45° W.; a second and later set striking N. 20° to 35° W. and dipping usually 50° SW., characterized by arsenopyrite, abundant free gold, and occasional particles of tetradymite, which have been incorrectly considered as telluride of gold by the prospectors in this region. These veins are narrow and gold is seldom found in sufficient quantity to encourage extended mining operations.

Wild Cat group.—The Wild Cat claims are located southeast of the Hoadley group and on veins of similar character occurring in a syenite intrusive in the schist formations. The schists strike N. 50° W. and dip 20° SW., while the dike trends N. 35° W. and dips 20°

SW. Two sets of veins occur, and, as at the Hoadley group, the pyrrhotite-bearing veins are the older. The developments consist chiefly of open cuts, short tunnels, and shafts. A sample test of 5 tons of ore from one of these veins is reported to have given high values.

Birdseye claim.—The Birdseye claim is located on the shore of Revillagigedo Island 4 miles south of Ketchikan. Although this vein was one of the first to be discovered in the Ketchikan district, little development has been accomplished. Surface stripping and a shaft 32 feet deep constitute the entire improvements. The vein which outcrops on the beach is 3 to 5 feet wide and occurs in a porphyry dike intrusive along the bedding planes in the slate-schist formation, striking N. 30° to 50° W. and dipping 45° NE. This dike, which varies from 10 to 20 feet in width, includes many fragments of black slate, and adjacent to the vein is impregnated with sulphide minerals. The minerals contained in the vein are pyrite, galena, zinc blende, and free gold. In the schist and black-slate country rock, quartz veins were also observed, though these are older than the porphyry dike and do not carry values.

Laskawonda group.—The Laskawonda property of three claims is located near Ketchikan and is reached by a well-constructed board walk which was to have served as a tramway. The developments consist of a shaft located half a mile from the town at an elevation of 175 feet and reported to be 85 feet deep, a short tunnel, and surface strippings. The ore body is a slightly mineralized band of the greenstone schist formation, striking N. 50° W. and dipping 50° NE., which is cut by a few small quartz veinlets. The metallic minerals contained are pyrite with some chalcopyrite, occurring in the quartz veinlets and in the greenstone schist. For the last few years work has been suspended on this property.

CLEVELAND PENINSULA.

General description.—Cleveland Peninsula lies between Behm Canal and Ernest Sound and its elongation coincides with the general trend of its constituent mountains. The general geology is comparatively simple; the northeastern part of the peninsula consists of the Coast Range granite, which is flanked on the southwest by the schist belt, which in turn farther south grades into the black slates or argillites. Near the southern end of the peninsula wide belts of greenstone and greenstone schists and occasional limestone beds are intercalated in the slates (see Pl. II).

Masses of intrusive diorite occur within the greenstone-argillite area, and in at least one place have been found to contain ore-bearing quartz veins. Between Helm Bay and Vixen Inlet is a conspicuous red-brown mountain made up of an immense intrusive mass of

peridotite with serpentine and ferric oxide as weathering products. The strata trend in general northwesterly, with local variations due to folding, and dip northeast at different angles. Near the granite contact, at Spacious Bay and Vixen Inlet, the beds are much folded and are in general flat lying, but to the south the strike becomes more uniform and the dip steeper and in places the dip is to the southwest. Quartz veins are widely distributed throughout the entire formation and have been prospected at only a few points. Prospectors in the region have learned by experience that the veins of value are confined essentially to a wide greenstone schist belt over 1 mile in width and extending from the west side of Helm Bay across the peninsula to Union Bay. The values are variable and, although occasionally high for a short distance, are low in average and must be mined economically in order to be profitable.

Gold Standard group.—The Gold Standard group, belonging to the Alaska Gold Standard Mining Company, embraces 17 claims located on the west side of Helm Bay about 2½ miles from the head of the bay and one-half mile from tide water (fig. 14). Discoveries at this point were first made in 1897, and in 1898 the ore from a rich ore shoot near the surface was treated in an arrastre and reported to have yielded about $20,000 in value. In 1899 a 5-stamp water-power mill was installed, several buildings erected, and a tramway built from the mine to the mill and from the mill to the beach one-half mile distant. During 1900 the mill was operated and considerable mining developments accomplished, but at the close of the year work was suspended. In the following years operations on a small scale were advanced, but not until 1906 did active work begin again, when a small shipment of high-grade ore is reported to have been made and a considerable output of bullion was made from the stamp mill. The mine is developed by a shaft starting at a point 225 feet above tide water and 150 feet in depth following the vein, and from this two drifts have been extended developing the ore in depth. Besides these workings short tunnels and several small shafts have been started at other points on this property.

The country rock at this locality is greenstone schist interstratified by argillaceous beds, the general strike being N. 25° W. and the dip 60° NE. Two systems of quartz veins occur in these schists, the older set, which are the larger veins, striking parallel with the schistosity, and the second or younger system following the general trend of the former but dipping 60° to 70° SW. and intersecting them in depth. The latter veins are small and often mere gash veins carrying little or no value except at those points where they intersect the veins of the larger system. The principal vein deposit, which is being developed at the shaft, is of the older system, varies from 6 inches to 6 feet in width and is exposed for over 1,000 feet along its strike.

The walls of the vein are well defined by slickensides with gouge on the foot-wall side and a seam filled with calcite carrying free gold along the hanging wall. Fault planes transverse to the veins were locally observed displacing the veins from 1 to 3 feet in a horizontal

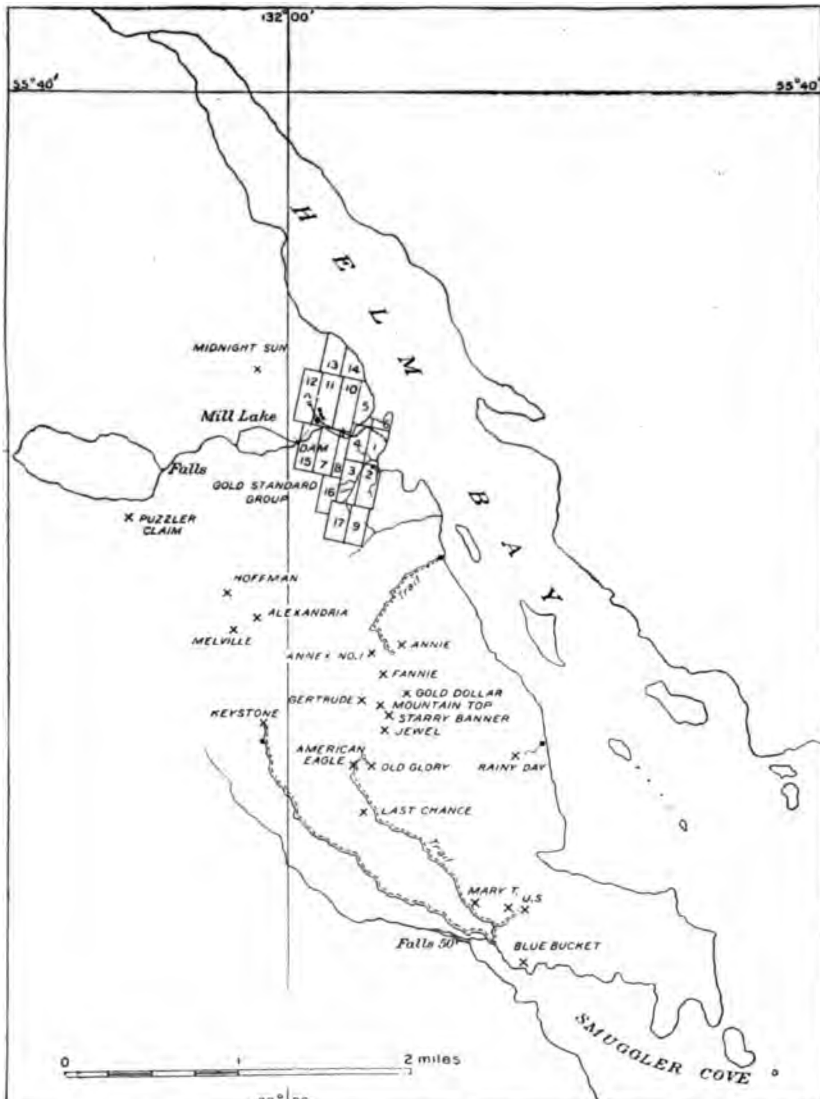

FIG. 14.—Sketch map showing positions of prospects and mining claims at Helm Bay, Cleveland Peninsula.

direction. The ore contained is essentially auriferous quartz with pyrite, and in the gash veins small crystals of tetradymite were noted. The largest percentage of the gold is free milling and can be extracted in the stamp mill by amalgamation. The concentrates,

which aggregate about 3 per cent of the ore, are saved for smelter shipment and are reported to carry high values.

Puzzler claim.—The Puzzler claim is situated on the south side of a lake 2 miles east of the Alaska Gold Standard and at an elevation of 400 feet (fig. 14). A tunnel 180 feet long has been driven through the greenstone-schist country rock, and at 60 feet from its entrance undercuts a lode deposit inclosed in a graphitic schist. Quartz veins also occur at this place, but are not so strongly developed. The same deposit is exposed by an open cut at 440 feet elevation, the lode being parallel to the schistosity of the country rock which strikes N. 50° E. and dips 60° SE. In this deposit two systems of quartz veins occur, which correspond in a general way to those at the Alaska Gold Standard deposit, though they are not so strongly developed, and the ore shoots are smaller. Slipping planes and fault seams are of common occurrence in this vicinity.

Midnight Sun claim.—The Midnight Sun claim lies half a mile west of the Gold Standard mine at an elevation of 560 feet (fig. 14). The vein deposit, which has been exposed by a 15-foot open cut, varies from 6 inches to 2 feet in width, striking N. 80° W. with a dip 30° NE. Slipping planes defined by slickensides are of common occurrence across the vein and indicate considerable movement and displacement of both the inclosing greenstone-schists and the vein subsequent to its deposition. Included in the vein are fragments of the schist, the mineral content being pyrite with free-gold particles.

Alexander, Hoffman, and Melville claims.—The Alexander, Hoffman, and Melville claims are situated near the top of the mountain 2½ miles from the head of Smugglers Cove and 1½ miles southeast of the Gold Standard mine (fig. 14). The prospects on these properties were located in 1902 and 1903. The greenstone and slate beds on this mountain are considerably folded and the direction of their strike and dip varies greatly. The vein deposits follow slipping planes transverse to the schistosity of the country rock and are parallel to it. On the Alexander claim a tunnel 45 feet long exposes a vein 6 inches to 3 feet in width striking north and south with dip 45° W., the footwall side being defined by a gouge seam 1 inch thick. The Hoffman claim includes an irregular vein deposit averaging 5 feet in width, striking N. 5° W. with a steep dip to the southwest. The inclosing greenstone-schist strikes N. 60° W. with a dip 70° NE., and in it are numerous faults showing small displacements. A tunnel 21 feet long has been driven along the vein, and pyrite was observed in it, both in the vein and in the inclosing schist. Fine gold is said to occur, though the average value of the deposit is low. The vein deposit on the Melville claim strikes N. 40° W., transverse to the trend of the inclosing slate and greenstone, which at this point is N. 15° E. It is peculiar because of the occurrence of arsenopyrite both in the

vein and in the adjacent slates, though where it crosscuts the greenstone this mineral is practically absent. The developments consist of a short tunnel and surface strippings from which a small amount of ore was mined and treated in an arrastre on the property.

Gold Mountain group.—From Smugglers Cove the greenstone-schist belt can be traced along the mountain ridge parallel with the east shore of Helm Bay over Gold Mountain. To the east and west of it black slates predominate. Gold Mountain has a maximum elevation of 2,120 feet, and on it a number of prospects have been located, the principal ones being the Annie, Mountain Top, and Starry Banner. On the Annie claim a 20-foot shaft was sunk in 1900 on a quartz ore pocket at a point 1,025 feet from tide water, and from this about $5,000 is reported to have been derived. At another point a tunnel 450 feet in length has been driven on a lode deposit striking N. 30° E. parallel with rock structure and from 10½ to 20 feet wide, in which veinlets from a few inches to a foot in width occur. From the tunnel a shaft 50 feet deep has been sunk and the deposit explored by a drift at this level. Pyrite and chalcopyrite were both observed, but as a whole the lode will average low in values.

On the Mountain Top claim an 8-inch vein striking N. 55° W. with a dip 25° NE. crosscuts the greenstone schist formation, which has a northeast trend and a vertical dip. The vein has been exposed by shallow shafts and open cuts, but is too small to be of great value.

On the Starry Banner claim a tunnel 225 feet long at an elevation of 1,950 feet has been driven in a N. 30° E. direction along an 8-inch quartz vein, which is parallel to the schistosity of the greenstone in trend but intersects it in dip. Along the sides of this vein calcite and epidote veinlets were observed in the country rock and in the vein near the surface the sulphide minerals were considerably oxidized.

Rainy Day claim.—The Rainy Day prospect is located less than half a mile from tide water opposite a small island on the west side of Helm Bay near its entrance. The mineral deposit at this locality is of interest because it occurs in a granite-porphyry dike which is from 600 to 1,000 feet wide and strikes N. 40° W. The vein deposit, which is 3½ feet wide, strikes northeast and has been exposed in a 105-foot tunnel at an elevation of 200 feet from tide water. Above the tunnel at 280 feet elevation is an open cut in which the vein is exposed, and at this point are prominent slipping planes striking transverse to the vein. The ore minerals are sphalerite, pyrite, and galena in small amounts, the principal values being in gold, which occurs native in fine particles.

Blue Bucket claim.—The Blue Bucket claim is situated near the northeast head of Smugglers Cove near the beach and has been developed by a short prospecting tunnel. The quartz vein runs irregularly through banded chloritic and sericite schists which strike N. 38°

W. and dip 65° NE. Pyrite cubes only were observed in the quartz. The values appeared to be low.

Keystone claim.—The Keystone claim is reached by a trail 2 miles in length which begins near the falls at the head of Smugglers Cove and follows in a northeasterly direction along the eastern valley slopes of Falls Creek. The mine workings are situated at an elevation of about 675 feet and consist of a long crosscut tunnel with drifts, the total length of which is nearly 700 feet. A shaft 65 feet deep has been sunk on the vein. The property has been idle during the last few years and was recently relocated under a new name. The country rock is a green, folded, faulted, chloritic schist striking in a general northwesterly direction with steep vertical dips. The ore body consists of a stockwork of stringer veins occurring in a mineralized belt of schist many feet in width, intensely sheared, and filled with slipping planes. The entire belt is heavily mineralized with pyrite and carries low values in gold and silver. The quartz veins vary in width and usually have free walls often with a coating of mineralized gouge. Calcite frequently accompanies the quartz gangue.

Mary T. and United States claims.—The Mary T. claim and the adjoining United States claim are located near the head of Smugglers Cove and both are practically in an undeveloped state. On the Mary T. claim an open pit exposes the ore body, which is essentially a belt of mineralized and indurated sericite schist. The ore consists of pyrite in well-formed cubes with some chalcopyrite and its weathering products, malachite and azurite. The values are reported to be low. On the United States claim a quartz vein occurs in chlorite schist in irregular lenses often parallel to the cleavage and contains occasional cubes of pyrite. It has been exposed chiefly by surface cuts and short prospect tunnels. The values reported are likewise low.

Last Chance claim.—The Last Chance claim, which has recently been relocated, is situated about 1 mile from Smugglers Cove, and like the preceding claims has not been developed to any extent. The country rock is chloritic schist striking about north and south; the ore body, a quartz vein of irregular width, is contained in a belt of mineralized schist, along which intense movement and shearing has taken place. In the short drift the values in gold are reported to vary and to give a low general average.

Old Glory group.—The Old Glory group of two claims including the Old Glory and American Eagle is situated on the west side of Gold Mountain at an elevation of about 900 feet and 1½ miles from Smugglers Cove. On the property the ore body has been traced by numerous open cuts and three short tunnels. The ore is treated in a 2-stamp mill, operated by a Pelton wheel. Only the gold which is retained by amalgamation is recovered, the auriferous concentrates being wasted because of lack of proper facilities. The bed rock con-

sists largely of folded greenstone schists and argillites striking N. 10° to 30° W. The veins are in general parallel to the rock structure, varying from a few inches to a foot in width, and in places the country rock is also impregnated with sulphide minerals, thus forming a lode deposit. Practically no work has been done on these claims during the last few years.

TWELVEMILE ARM.

GENERAL DESCRIPTION.

The narrow body of water called Twelvemile Arm extends southwesterly from the head of Kasaan Bay and terminates in a low-lying river valley, over which a long portage is reported to lead to Big Harbor on the west side of Prince of Wales Island. The mineral deposits discovered in this area have been chiefly gold-bearing veins, copper being of only subordinate interest. The most important mines are the Crackerjack and the Puyallup, situated a short distance from Hollis (fig. 15). In general, mining activity in recent years has been slight and little more than annual assessment work has been accomplished on most of the prospects since the visit of Mr. Brooks in 1901. In the immediate vicinity of Twelvemile Arm and along its shores the country rock consists chiefly of altered argillaceous sedimentary rocks, often schistose, and intruded by extensive granite masses and later porphyry dikes. Belts of greenstone, both massive and schistose, are frequently interstratified with the slates and limestones, but have not yet been found to be mineralized to any extent in this particular area. Directly west of Hollis is a belt of black graphite slates trending about N. 30° W., which contains the principal vein deposits and which has been traced northwest beyond the Crackerjack mine for several miles to where it is cut off by the granite massif of Granite Mountain. Along this contact, which is well exposed, about 1 mile south of the Granite Mountain claims, evidence of a fault of considerable magnitude can be seen. The granite at the contact sends no apophyses into the invaded slates, indications of contact metamorphism are wanting, and the slate belt near the contact is intensely shattered and bears all signs of extended movement. The slate belt near the Crackerjack mine has been folded into a large anticline, on the southwest flank of which the Crackerjack veins are located, while at the Puyallup mine the beds dip 35° to 45° NE. These slates grade to the east into coarser graywackes and altered conglomerates. Farther south on Twelvemile Arm limestones and calcareous schists are more abundant and trend approximately parallel to the shore with an easterly dip.

The ore deposits in this area are confined chiefly to the black slates seen at the Crackerjack claims and to the Granite Mountain massif.

The veins are well defined and persistent, usually following intrusive dikes or fracture planes and jointing planes in the country rock. The values are chiefly in gold, with some lead and silver and a little copper. Some of the veins carry locally free gold, but as a general rule the average content is not high.

FIG. 15.—Sketch map showing location of claims near Twelvemile Arm, Prince of Wales Island.

PROSPECTS IN THE VICINITY OF HOLLIS.

Puyallup mine.—The Puyallup mine is situated about 1¼ miles **from** tide water and is connected with Hollis by a tramway, at the **end of which** is a 5-stamp mill. The group embraces three claims, **on which** the veins have been traced and developed by several tunnels

and shafts. The country rock is slate with altered porphyries and clastic breccias, the general trend being N. 25° W. and the dip 50° to 60° NE. The quartz veins follow planes of weakness and movement along the strike and have been exploited by several tunnels, the longest measuring 1,135 feet. In the long tunnel two veins are exposed, following the walls of a porphyry dike in the altered slate, the vein along the hanging wall of the dike being richer than the foot-wall vein. Near the face of this tunnel faulting has disturbed the even trend of the vein and added considerably to the difficulties of mining. This pay vein, which averages about 6 inches in width, is exposed in a lower 1,200-foot tunnel for a length of 220 feet and has been traced by outcrops on the surface for about one-fourth of a mile. An upper tunnel, 150 feet above and 900 feet southwest of the main tunnel, has been driven 90 feet on another vein. In this tunnel the vein is considered identical with the pay vein of the long tunnel. The ore is free-milling, 85 per cent of the total value being free gold. The mine has been worked in only a desultory way in recent years, and the production has been small.

Crackerjack mine.—The Crackerjack group of claims is located south and southwest of the Puyallup, with which it is connected by an excellent trail (see Pl. I and fig. 15). Surface improvements consist chiefly of quarters for miners and an ore chute for transporting ore to the Puyallup stamp mill. The Crackerjack vein is an unusually persistent vein and has been followed by surface croppings and test pits along a number of claims. On the Crackerjack claims proper it occurs along the hanging and foot walls of a 16-foot porphyry dike intrusive along the bedding planes of black slate, striking in general N. 25° W. and dipping 35° SW. The slate is finely laminated and more or less graphitic. The vein varies in width from a mere seam to 5 feet. Its metallic minerals are pyrite, galena, zincblende, and a black, soft sulphantimony or bismuth mineral, the exact nature of which was not determined; the gangue is essentially quartz with some calcite. The dike itself is characterized chiefly by widespread epidotization and pyrite impregnation. The No. 1 tunnel at 800 feet elevation crosscuts the formation for about 215 feet, at which point the vein is encountered and followed in a southerly direction for about 675 feet. In the crosscut several minor veins were encountered, but were not followed. The gold values in these veins occur in shoots, two of which have been stoped out for 35 and 40 feet above the tunnel level. Occasionally streaks are encountered which give high assay values in silver. The amount of gouge on both sides of the dike is indicative of considerable movement along the fissure planes. Minor transverse slipping planes were also noted, but apparently do not affect the veins materially. In Tunnel No. 2, which is

400 feet in length, at 1,050 feet elevation, both the dike and the vein were observed to crosscut the formation at one point for about 80 feet and then to resume their normal parallel trend.

Hollis group.—Still farther up the mountain at 1,500 feet elevation a vein similar to the Crackerjack vein has been discovered and explored by a tunnel 400 feet long. The conditions here are analogous to those in the Crackerjack tunnels, including the slate belt, trending and dipping in the same general directions, but the porphyry dike is somewhat wider. The quartz vein was observed to branch out into the porphyry so that for some distance two parallel veins have been followed by the drifts. The walls are well defined and the ore shoots well marked. The black slate belt has been traced still farther south and west over the summit of Hollis Mountain and down into the Harris River valley, where claims have been located on mineralized veins similar in character to the Crackerjack vein. The persistence of these veins is a strong argument for their continuation in depth. The ore production from the entire system of veins has been slight, the work having been devoted chiefly to developing and testing the ore bodies.

Harris River claims.—As stated in the preceding paragraph, the mineral belt on which the claims on the mountain slope north of Harris River are situated is the continuation of the Crackerjack black slate formation. A number of claims, including the Julia, the Humboldt, the George Nos. 1 and 2, and the Keokuk Nos. 1 and 2, have been located in this area and developed to some extent. The general aspect of the mineral deposit on these claims is similar to the Crackerjack deposit. On each claim the developments consist of surface strippings, test pits, and short tunnels. Pyrite, galena, and zinc blende, with occasional free-gold particles, constitute the metallic minerals and quartz and calcite the gangue minerals. Porphyry dikes occur with many of the veins.

Recently considerable work has been done on the Julia claim, the ore shoot of which outcrops in the bed of Harris River. An inclined shaft 200 feet deep has been sunk to undercut this ore shoot, and at the 50-, 100-, and 150-foot levels, drifts have been extended, 35 feet long on the 50-foot level and 80 feet long on the 100-foot level. The ore shoot is reported to be about 60 feet long and from 2 to 5 feet wide and to carry high values in gold, 50 per cent of which is free milling.

Cascade group.—The Cascade group is located about 2 miles south of the Puyallup mine and at an elevation of 1,300 feet. The developments consist chiefly of two drift tunnels, and in the upper one a quartz vein is well exposed. The vein averages 2 feet in width and fills an old fracture crack in an altered basic intrusive. The lower

tunnel, which was driven to undercut the vein, is 300 feet in length and crosscuts intrusive rocks and dikes of several different types, but does not expose the vein. The original sedimentary rocks in this area have been profoundly altered by the intrusives, and epidotization is widespread. The vein strikes N 53° W., dips 70° SW., and has been followed for about 175 feet in the upper tunnel. Its metallic minerals are pyrite, zinc blende, galena, and gold, with quartz and calcite gangue. The values in this vein are very unevenly distributed and the average content is probably not high, although fragments of exceedingly rich ore have been found. Above the Cascade group the Mountain Bell group of three claims has been located on a narrow quartz vein reported to carry good values in free gold.

Dolly Varden claims.—The Dolly Varden group of claims is located in the limestone formation about 1½ miles southeast of the head of Twelvemile Arm, and at an elevation of 1,100 feet. The marble occurs as a member of the greenstone slate formation exposed along the shores of Twelvemile Arm. The veins are essentially later impregnations along the bedding of the marble strata and strike N. 15° E. with steep to vertical southeast dip. Gray copper is the essential metallic mineral, and is in many places altered to azurite and malachite. Very little development work has been accomplished on this group. Several other claims on similar veins and country rock have been located in this area, but were not visited by the writers.

Stella claim.—The Stella claim is situated about one-half mile north of Clark Bay, a small indentation 2½ miles northeast of Hollis. The quartz vein occurs along the contact of a diorite-porphyrite dike in black slate and has been explored by a tunnel 540 feet in elevation and 130 feet long. It averages 3 feet in width, strikes N. 40° W. and dips 80° NE., and is separated from the black slate foot wall by a band of gouge 1 inch thick. The metallic minerals are pyrite, galena, and zinc blende, with quartz and calcite gangue, and occasional included fragments of black slate. The values in precious metals are low.

Flora and Nellie claims.—The Flora and Nellie claims are situated about 8½ miles by trail northwest of Hollis. The ore body which is being exploited at this point is a quartz vein, averaging with gouge about 4 feet in width and filling an old shearing plane in diorite-porphyrite. Two tunnels have been driven on the vein, a lower one at 1,460 feet elevation and 390 feet in length, and an upper tunnel 90 feet in length; a shaft and winze have also been sunk on the vein. The quartz vein strikes N. 70° E., dips 60° SE., and is heavily mineralized with pyrite, chalcopyrite, galena, and zinc blende. The lines of movement in the diorite-porphyrite pitch at very low angles, indicating nearly horizontal fault movements. The values from this vein are reported high in gold and silver with some lead and copper.

At present transportation facilities are a serious problem in the systematic development of the claims in this area.

The southern extension of this group is called the Red Jacket claim, and on its surface stripping only has been done, and that chiefly in glacial drift covering the bed rock. To the northeast the Commander group of two claims has been located on the continuation of the Flora and Nellie vein and outcrops along a steep gulch up the mountain side. On this group two drift tunnels have been driven, the lower one at 1,680 feet elevation and the upper one at 1,825 feet elevation. In these the vein averages about 18 inches in width, with a wide band of soft gouge on the hanging-wall side, and strikes N. 75° E., with dip 65° SE. Near the vein the porphyry is altered considerably and often heavily charged with pyrite. The assay returns indicate high gold content with some silver. The metallic minerals are pyrite, chalcopyrite, galena, and zinc blende in quartz gangue.

Rose and Dew Drop claims.—The Rose and Dew Drop claims are located above the Commander group and extend over the ridge for some distance down its north slope. These claims are 2,300 feet above sea level and are located on a vein deposit along a slipping plane in a basic intrusive rock. The vein varies in width from 6 to 14 inches, strikes N. 60° W., dips 85° SW., and has been developed by two short drifts. The values are reported to average well in gold and silver.

Constitution group.—On the opposite side of Salmon Lake valley and about 3 to 4 miles north of the Dew Drop claim is located the Constitution group, which is reached most readily by trail from Karta Bay, via Karta and Salmon lakes and up the Salmon Lake valley, a distance of 11 to 12 miles. Here are two tunnels, the lower being at 2,000 feet elevation and 130 feet in length. In this the quartz vein varies from 6 inches to 4 feet in width and trends N. 65° W. to N. 45° W. with a vertical to 60° SW. dip. It occurs filling a shearing plane in gabbro and amphibolite and is lined frequently on both sides with soft gouge. Vein minerals are pyrite, chalcopyrite, galena, and zinc blende, the surface oxidation of the sulphides being unusually pronounced. In the face of the tunnel a transverse slipping plane appears to have cut off the vein. With present conditions of transportation further development of this group does not seem feasible.

Independent group.—The Independent group of two claims is located several miles west of the Constitution group and at the head of the glacial valley of Salmon Lake. The developments are confined to short tunnels and surface strippings. On the lower claim at 1,300 feet elevation the vein is 1 foot wide, strikes N. 75° W., dips 75° SW., has free walls and occurs along a shearing plane in altered porphyry (andesite), which is included in a generally much-altered sedimentary complex. The metallic minerals are galena, pyrite, and

zinc blende in a quartz and calcite gangue. The vein is reported to give very high assay values in free gold. At the tunnel on the upper claim, at 2,100 feet elevation, the vein is 1 to 2 feet wide, including gouge, and strikes N. 78° W., dips 75° SW., and is exposed chiefly along a steep gulch leading down the precipitous mountain slope. The country rock consists of altered slate and graywacke, crosscut by dikes of porphyry. At present these claims are too inaccessible to be of great value.

PROSPECTS ON GRANITE MOUNTAIN.

General description.—The claims on Granite Mountain can be reached most easily by trail from Karta Bay via Karta Lake; a longer and less satisfactory trail leads in a northerly direction from Hollis (fig. 15). Granite Mountain is made up almost entirely of massive granite which is remarkably homogeneous and free from dikes, particularly of the siliceous aplitic varieties. The veins are without exception quartz veins filling well-marked fracture planes in the granite; these planes are sharply marked and remarkably uniform in direction and thickness. The veins are likewise strikingly similar in appearance and mineral content, the quartz being usually stained to a brown-red color. They are characterized by free walls and undoubtedly persist in depth. Frequently the fissures or jointing planes in the granite are filled with diabase dikes which have subsequently been fractured, and in these spaces the mineral-bearing solutions have deposited auriferous veins.

Treasure group.—The Treasure group of twelve or more claims is located on the east side of Granite Mountain about 1½ miles from Karta Lake. The developments consist of two tunnels, the upper, at 1,380 feet elevation, following the vein for 450 feet. The vein varies from 1 to 2 feet in width and follows the hanging wall of an altered diabase dike rock in the granite. Its general strike is N. 55° W. and its dip from 60° to 80° NE. This vein has been traced up the mountain slope along a steep gulch and over the summit for a mile, five claims being located on this vein alone. At the upper tunnel considerable ore has been extracted and placed ready for transportation. The metallic minerals are free gold, pyrite, galena, and chalcopyrite. The pyrite crystals are frequently coated with a deep-brown lustrous oxidation crust and the chalcopyrite occasionally shows green staining. Movement along the vein is indicated by the soft mineralized gouge, which is frequently found along the vein walls. The country rock, for which the general term "granite" is used, is a granitoid rock varying in composition from diorite to gabbro and is often strongly epidotized.

The second set of five claims is located on a deposit in a fracture plane, striking N. 20 E. and dipping 20° NW. This vein crosses

the first vein about 500 feet above the upper tunnel and likewise is contained in the granite country rock. The width varies from 1 to 3 feet and the values are lower than those contained in the northwest striking veins.

Clipper and Cutter groups.—The Cutter group of two claims and the Clipper group of three claims are located on the east side of Granite Mountain, south of and above the Treasure group. The improvements on these claims consist chiefly of surface strippings and short test tunnels. The veins are similar in appearance to the Treasure veins and strike in general N. 55° W., with a dip of 60° NE. They occur in granite or within diabase dikes which intrude the granite. At 2,900 feet elevation the vein on the Clipper group is 8 inches wide and occurs in a diabase dike 20 feet wide, which is much altered and decomposed. At 3,040 feet elevation the vein is 12 to 18 inches wide, but otherwise unchanged in aspect. The Cutter claims, 1,000 feet to the north, are practically identical in all respects and are reported to carry good values in gold.

Buckhorn group.—The Buckhorn group of nine claims is located on the west slopes of Granite Mountain, near the summit. The vein, which has been exploited by open cuts and by several tunnels, one at 3,100 feet elevation and the second at 3,000 feet, occupies a fissure in the granite, averages about 15 inches in width, and has been traced for several miles, striking N. 5° W. and dipping 45° NE. This vein is similar in character to the Treasure vein and is said to carry good values in gold.

Lucky Find group.—The Lucky Find group of four claims is located on a vein deposit striking N. 45° W. and dipping 60° NE. In the 50-foot tunnel at 2,450 feet elevation the vein is 1 foot wide and occurs between a diabase dike and the inclosing granite. The metallic minerals are pyrite and chalcopyrite, with quartz, calcite, and possibly siderite as gangue. Well-defined gouge marks the walls on both sides.

Lucky Jim group.—The claims in the Lucky Jim group are situated near the southwest side of the summit of Granite Mountain and are located on a quartz vein striking N. 25° W. and dipping 40° NE. and similar in every respect to the other veins of this area. The metallic minerals are altered pyrite, galena, malachite, and azurite.

Other claims.—Other claims on the north side of Granite Mountain, near Salmon Lake, namely the Go-by group and the Juneau group, were not visited by the writers, but are said to be located on veins similar in character to those already described and are reported to carry good values in gold. In this region the question of transportation is necessarily an important factor, and on its solution depends the future of many of these claims. At present profitable

mining, even in a small way, is almost out of the question owing to the inaccessibility of the region.

CHOLMONDELEY SOUND.

GENERAL DESCRIPTION.

Cholmondeley Sound is a deep inlet entering the east side of Prince of Wales Island. Ten miles from the entrance it divides into two long arms, the West Arm and the South Arm, each of which is 8 miles in length. On its south side, about 8 miles inside the entrance, is Dora Bay, 3 miles in length and 1 mile wide, forming a good harbor; and 2 miles east of this is Kitkun Bay, which may be entered only at high slack water, its entrance being shallow and obstructed by hidden reefs. Near the entrance to the sound the mountain declivities are gradual and heavily timbered, whereas from both South and West arms the valley slopes rise abruptly to higher altitudes, terminating in peaks 3,000 feet or more in elevation. On few of these does timber grow above the 1,500-foot contour. A low pass 4 miles in length extends from the head of the West Arm to the head of Hetta Inlet, and across this a Government road has been constructed, so as to form an easy route of travel and means of transportation for light freight from Ketchikan to Sulzer and Coppermount on the west coast of Prince of Wales Island. A second pass 6 miles long extends from South Arm southward to the head of Klakas Inlet. This, however, is used only by the natives. Still a third pass, connecting with a chain of lakes, extends from Dora Bay southeast to the head of North Arm.

The bed-rock geology of this section of the island includes alternating bands of greenstone and sericite schist and limestones, the latter usually altered to marble (Pl. I). These all have a general N. 50° W. strike with steep dips usually inclined to the northeast. Invading these stratified formations are huge intrusive masses of granite and diorite, which are exposed along the north shore of the sound and form the mountains west of Dora Bay. Dikes of diabase and other porphyritic rocks noted in adjacent areas are also present in this section.

The ore deposits within the area consist principally of auriferous quartz veins, both in the greenstone schist and along lines of brecciation in the limestone, the latter being comparable with those at Dolomi to the southeast, which are described below. Vein deposits rich in galena ore carrying silver values are also being developed.

PROSPECTS SOUTH OF CHOLMONDELEY SOUND.

Gladstone group.—The Gladstone property of four claims lies on the south side of the sound, 3 miles east of the entrance to Kitkun

Bay, and extends in an easterly direction for a mile from tidewater (fig. 16). These were located in 1904, and considerable prospecting by way of tunnels and open cuts has been done on all the claims, though no extensive developments have yet been undertaken.

The rock exposures on this group of claims consist essentially of limestone, which in places is banded and siliceous and in places schistose, the structural lines striking N. 35° W. The ore bodies consist of two or more parallel quartz ledges including many fragments of the limestone country rock, and are in general parallel to the bedding planes of the inclosing rock, but in places crosscut them at small angles. The veins vary from 1 foot to 4 feet in width and are exposed at intervals for two claims in length.

On the Gladstone No. 1 claim, 800 feet from and 140 feet above tide water, an open cut and tunnel have been driven on a 3-foot vein for 36 feet, along which an altered diabase dike apparently forms the hang-

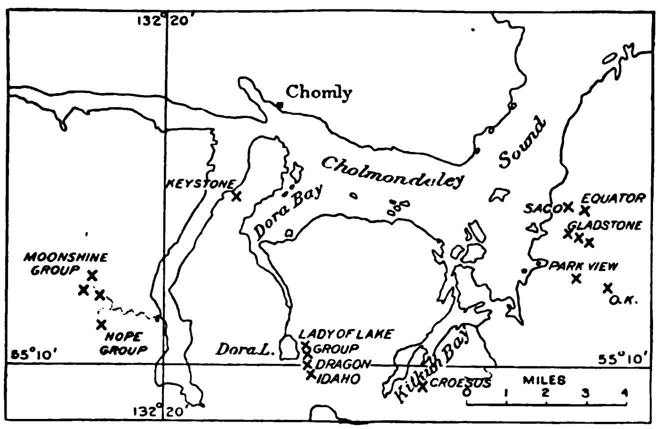

FIG. 16.—Sketch map showing positions of prospects in vicinity of Cholmondeley Sound and Dora Lake.

ing wall. This vein contains pyrite and chalcopyrite in a gangue of quartz calcite and some graphite. One hundred feet south of this a second vein 1 foot to 2 feet wide has been exposed by an open cut at 210 feet elevation. Higher up the hill, at 270 feet elevation and 500 feet east of the tunnel, the vein has a width of 4 feet and shows considerable sulphide ore.

On Gladstone No. 2 claim the general east and west strike of the veins gradually changes to a N. 60° W., the dip being 85° NE. At 400 feet elevation an open cut exposes a 6-foot vein for considerable distance along the strike, and similar showings have been made at various other points on this and the two adjoining claims extending to the summit of the divide at 850 feet elevation, though it is doubtful if any of these deposits are continuous for so great a length as is generally supposed.

Equator group.—The Equator group of claims lies one-half mile northeast of the Gladstone group on the south side of Cholmondeley Sound (see fig. 16). This property was located in 1902, but no extensive developments have been accomplished. The principal workings are located at 350 feet elevation, a half mile from tide water, and consist of a 50-foot tunnel along the ore body. The mineral deposit is a quartz vein 3 feet wide, containing masses and fragments of the inclosing limestone country rock, striking N. 60° W., parallel to the limestone bedding planes, and dipping 50° SW., cutting the planes at a small angle. Chalcopyrite and pyrite form the sulphide minerals, and the values are essentially in gold. The same vein has been exposed by open cuts at points higher up the hillside.

Saco claim.—The Saco claim, located in 1905, lies just below the Equator claim, at 200 feet elevation, on the southwest side of a gulch. On it a 50-foot tunnel exposes a vein deposit 4 feet in width at its mouth and narrowing to 2 inches at its face. The inclosing rock is a talc schist striking east and west, the trend of the vein being N. 45° E. with vertical dip. Scattered through the vein are small masses of chalcopyrite and pyrite, carrying small values in gold and silver.

Park View and O. K. claims.—The Park View and O. K. prospects are located on the south side of Cholmondeley Sound, at an elevation of about 900 feet and 1½ to 2 miles from tide water. The mineral deposits on these claims were discovered in 1905 and have been developed by surface stripping and open cuts. On the Park View claim a 5-foot belt of mineralized schist parallel with the inclosing schists and striking N. 75° W. has been exposed by an open cut and a pit 8 feet deep. This lode deposit includes stringers and kidneys of quartz and calcite, and chalcopyrite and pyrite are finely disseminated in the veinlets and the schist. The average values are reported to be low, and it is doubtful if ore sufficiently high in grade to mine will be found.

On the O. K. claim, three-fourths of a mile to the west, on the west slope of the ridge, practically no work has been done. The deposit is a well-defined quartz vein striking N. 75° W. and following the contact between a schist to the north and a limestone belt to the south. The vein is 3 to 4 feet wide and is exposed 100 feet in length, containing chalcopyrite, pyrite, sphalerite, and small amounts of galena, and is reported to carry copper and gold.

PROSPECTS AT KITKUN BAY.

Washington and Oregon claims.—The Washington and Oregon prospects are situated on the southeast side of Kitkun Bay one-fourth mile from tide water. They were first located in 1900 as the Maggie May group, and in 1904 were relocated under the above names. Most of the development work consists of wide open cuts and

has been done on the Washington claim near its junction with the Oregon at an elevation of 300 feet (see fig. 17). The ore body consists of a 10-foot band of brecciated limestone and schist, traversed by a network of quartz stringers and veinlets carrying small amounts of sulphide ore. The strike of this lode deposit is N. 45° E., crosscutting the general trend of the inclosing country rock, which is to the northwest. About 200 feet east of this belt is a vein deposit 3

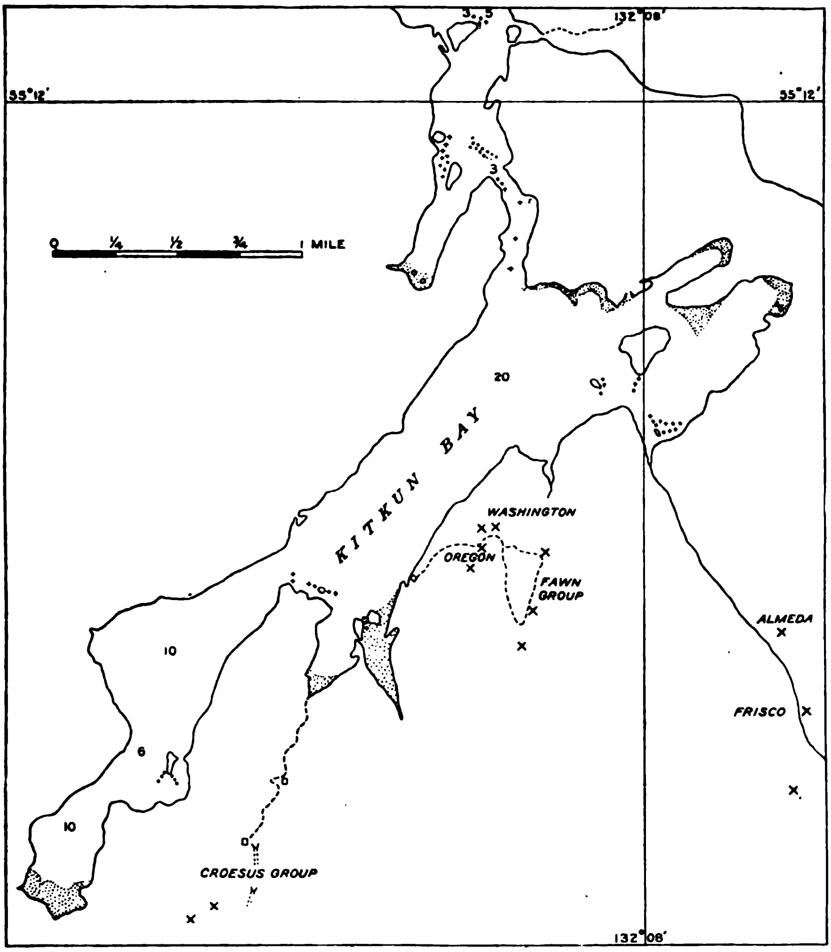

FIG. 17.—Map of Kitkun Bay, showing location of prospects.

feet wide, striking N. 30° E. with vertical dip and crosscutting the chlorite schist country rock. In this vein pyrite, chalcopyrite, and sphalerite occur, containing small values in gold and silver.

Kid group.—The Kid group of three claims lies one-fourth mile east of the Washington claim. The property was originally located as the Fawn group and is described by Mr. Brooks in his report, but

since his visit in 1901 little development work has been done, and in 1905 the claims were relocated as the Kid group. Greenstone schists with intercalated limestone beds form the country rock and have a nearly east and west strike with a dip 45° N. Three parallel quartz veins striking N. 30° E. with a vertical dip have been prospected on these claims. On claim No. 2 is a tunnel 30 feet long at 650 feet elevation, exposing a vein 4 feet wide, which has been traced for a considerable distance along the surface, following the principal direction of slipping planes and jointing in the country rock. At one point it was crosscut by a diabase dike of more recent intrusion than the ore deposition. The vein is essentially quartz, carrying small amounts of pyrite, chalcopyrite, galena, and sphalerite. About 150 feet east of this tunnel is the second vein, which is from 4 to 8 feet wide and outcrops along the surface for a considerable distance. Where opened by surface cuts, pyrite contained in a gangue of quartz and calcite was the principal sulphide mineral.

The third vein lies 50 feet farther east, and has been explored by several open cuts, exposing a vein 6 feet in width with included fragments of schist in which sulphide minerals were finely disseminated. This vein, as also the other two, are reported to contain but a few dollars in metal values.

Alameda and Frisco claims.—The Alameda and Frisco claims, which are also undeveloped prospects and represent relocations of the Tom Boy claims Nos. 1 and 2, are situated along a gulch one-half mile from tide water and 1 mile southeast of the Washington claim. On the Alameda claim, at 750 feet elevation, is a vein deposit 4 feet in width striking north and south with a dip of 50° east, and at 850 feet elevation the same vein is exposed on the east bank of the gulch. The deposit was essentially of quartz, containing very little mineral, and is said to be low in gold value. At 1,000 feet elevation, on the Frisco claim, a 12-foot vein deposit striking north and south has been opened by a surface trench, and in the vein are included fragments of the schist and limestone country rock, and small particles of pyrite. The vein is said to carry but a few dollars in gold values. Above this claim, at 1,050 feet elevation, on the divide between Kitkun Bay and Dolomi or Johnson Inlet, a slightly mineralized lode deposit 30 feet in width is exposed and forms a small ridge protruding above the schist. This is also reported to be of too low grade to mine.

Croesus group.—This group embraces sixteen claims extending 1 mile inland from the south end of Kitkun Bay. They were first located in 1899 and are described by Mr. Brooks, who visited the locality in 1901, at which time energetic developments were being advanced. Since 1902 operations have been suspended. At a point 600 feet in elevation and three-fourths mile from the bay is the Croesus tunnel, 360 feet in length. This follows a quartz vein varying from a

width of 4 feet at the mouth to 4 inches in width at the face of the tunnel and striking south with a dip of 85° E. The country rock is a greenstone schist alternating with beds of limestone and striking N. 70° W. with a dip 70° NE. Above this tunnel at 750 feet elevation a second tunnel 135 feet long has been driven along the same quartz vein, though in this the width of the vein was much smaller, varying from 2 to 8 inches. Rich ore is reported to have been taken from this vein, but the pay streaks are small and in places were faulted, thus discouraging further developments. About a half mile southwest of these workings is the San Juan claim, on which at a point 500 feet in elevation a crosscut tunnel 320 feet in length has been driven in a S. 65° E. direction, and above this a second tunnel 20 feet long has been driven, though in neither tunnel was ore exposed. At 680 feet in elevation a quartz vein 6 feet wide striking N. 20° W. with a dip 30° NE. Some high assays have been obtained from the ore in this vein, but its average value is low. Other prospects have been located in this vicinity on similar vein deposits, but these were not visited by the writers.

PROSPECTS AT THE HEAD OF DORA BAY.

General description.—Dora Bay is a narrow inlet 3 miles long on the south side of Cholmondeley Sound (fig. 16). At its head a stream one-half mile long connects with a lake 1¼ miles long, and at the head of the lake the mining prospects are located. These may also be reached by a trail from the head of North Arm. The limestones and schist constitute the principal bed-rock exposures within this area, and on the west side of the bay these are intruded by a wide area of granite, which also forms the west shore of Dora Lake. The mineral deposits are veins in the limestone and schist and contain values principally in silver and lead with only small values in gold, the ore minerals being galena, sphalerite, pyrite, and chalcopyrite.

Lady of the Lake group.—The Lady of the Lake claims, three in all, are located just above the southwest end of Dora Lake 1¾ miles from the bay. At 220 feet elevation a crosscut tunnel 68 feet long undercuts a vein deposit 3 to 8 feet wide along a plane of brecciation in the calcite-schist country rock. At its outcrop 60 feet above the tunnel the vein has been opened by surface trenches along its strike, which is N. 10° W. with a dip 50° SW., parallel to the bedding planes of the inclosing limestone country rock. The contained minerals are galena and sphalerite, with some pyrite and chalcopyrite, and the values contained are in gold and silver. No work has been done during the last few years on this property.

Oregon and Idaho claims.—The Oregon and Idaho prospects were originally located as the Frisco group in 1899, and in 1903 were relo-

cated under the above names. They are situated just south of the Lady of the Lake group and half a mile from the western end of Mineral Lake, tributary to North Arm. The rock exposures consist of decomposed and slightly mineralized schist striking N. 20° W. and dipping 70° SW. The ore body is a well-defined vein deposit 3 feet in width striking N. 20° E. with a dip 70° SE., and follows the 150-foot contour of the mountain slope for several hundred feet. It has been developed by pits and open cuts and contains sphalerite, pyrite with some galena, and chalcopyrite. The ore body is not large and the values are said to average but a few dollars.

DOLOMI.

General description.—Dolomi is a small mining town at the head of a small bay on the north side of Johnson Inlet, which has its entrance south of Cholmondeley Sound. Tributary to this bay are two broad, low-lying valleys occupied by lakes, the one trending to the north and the other to the west. The surrounding mountains are relatively low, with gradual slopes densely wooded to their summits.

The rock exposures are the continuation of the limestone and schist belts exposed in Cholmondeley Sound to the north and having an east and west strike (see Pl. I). The rock beds at this point are closely folded, and the limestones are altered to marble, which is often banded blue in color and siliceous. The schists are made up principally of greenstone material, chiefly indurated tuffs, and interbedded with them are sericite and argillite schists. Numerous dikes of diabase intrude these rock beds as well as the ore deposits.

The ore bodies are typical examples of the breccia veins and usually strike parallel to the general structural planes of the altered limestone and siliceous schist country rock. Along these planes the mineral solutions have circulated, depositing quartz and various metallic sulphide minerals, which together form the cementing material of the brecciated limestone fragments. These included rock fragments, as well as the inclosing wall rock, are largely replaced by the ore-bearing minerals. These deposits vary from 2 to 10 feet in width and are often traceable for 1,000 feet or more. The minerals contained are fine gold, tetrahedrite, galena, sphalerite, chalcopyrite, and pyrite, with quartz and calcite as gangue. At the surface exposures the tetrahedrite and chalcopyrite are in some instances altered to malachite and azurite, which tinge the veins with characteristic green and blue colors. In this type of deposit the richer ore generally occurs in the form of shoots within the vein, pitching at an angle to its dip. Of the many veins that have been prospected, the Valparaiso, Paul, Amazon, and Golden Fleece are best known. Since 1898 prospecting has been done in this vicinity, and a vast number of claims have been lo-

cated and partially developed, but only those properties on which the larger ore bodies have been exploited will be described in the following pages. From two mines, the Valparaiso and Golden Fleece, a small production of high-grade ore was made in former years, but of la'e mining progress has been retarded by litigation. But this difficulty is said to have recently been overcome.

Valparaiso group.—The Valparaiso group of claims includes several locations along the north side of Paul Lake, from 1 to 2 miles from Dolomi, and are connected with the head of the bay by a surface tramway (fig. 18). The principal development work has been advanced on the Valparaiso claims Nos. 1 and 2, and on the Paul and

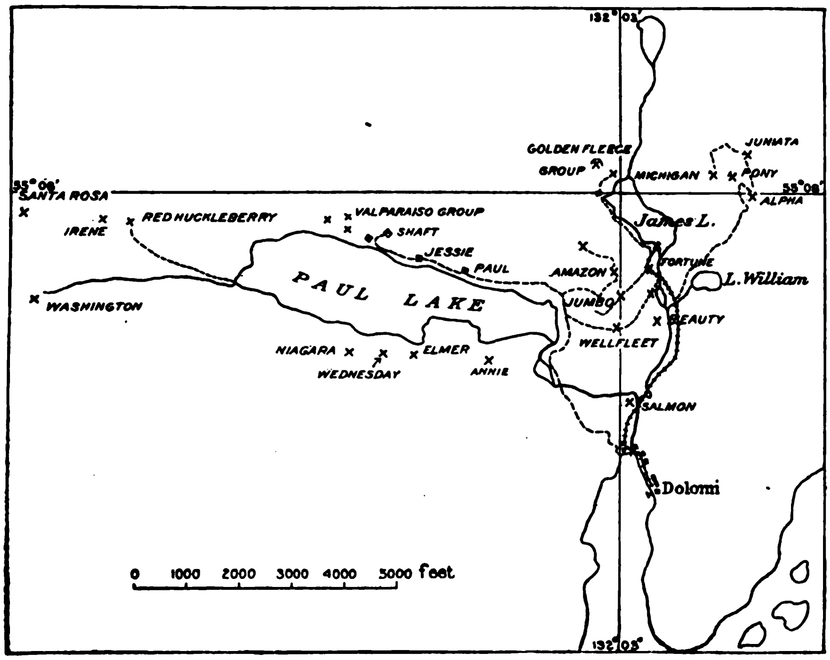

FIG. 18.—Sketch map showing mines and prospects near Dolomi, Prince of Wales Island.

Jessie claims. The Valparaiso claims are located from 80 to 100 feet above and one-fourth mile from the northwest end of Paul Lake; the workings consist of two shafts 150 and 225 feet in depth, from the latter of which 90, 150, and 200 foot levels have been extended along the vein 175, 350, and 250 feet, respectively, in length. On the Paul and Jessie claims, along the north shore of Paul Lake, several shafts have been sunk from 10 to 60 feet, following the veins, and various cuts expose the ore body along the surface. The Valparaiso vein is probably the largest and most extensive of the ore bodies that have been discovered in this section. It has been traced several thousand feet and averages from 4 to 10 feet in width. It has a N. 55° W.

trend and dips 30° to 50° NE., the variation being due to the folding and flexing of the inclosing limestone beds, with which the vein is in general parallel. Taken as a whole, the vein is of moderate grade ore, but several ore shoots containing high values have been found in it, and from the main shaft on claim No. 1 a considerable amount of this ore has been mined. The following figure presents a cross section and plan of the ore shoot in this vein as exposed at these workings (fig. 19). The ore shoot is confined to the foot wall, and pitches 60° SE. The central portion of the vein is made up of limestone breccia in a quartz matrix, and on both the foot and hanging wall sides it is defined by veins of massive quartz. Slipping planes along which gouge matter is present were observed striking parallel with the vein. The ore minerals are tetrahedrite carrying free gold, chalcopyrite, and some pyrite.

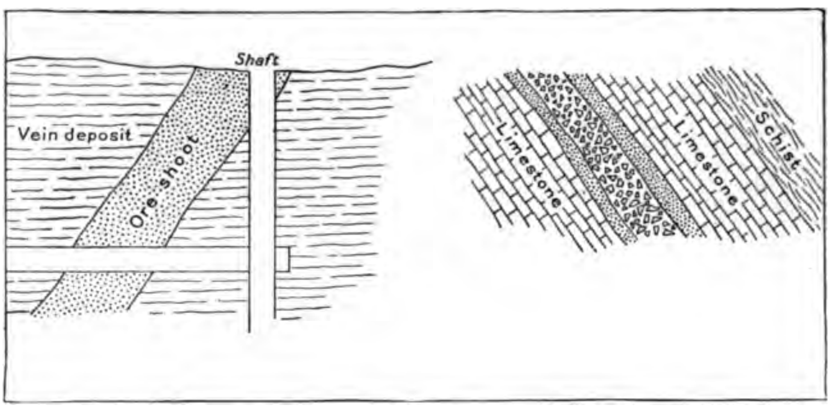

FIG. 19.—Sketch of mine workings at Valparaiso mine, Dolomi, showing position of ore shoot.

The veins exposed on the Paul and Jessie claims are similar to the Valparaiso vein and have fairly well-defined walls. The principal vein, which has been developed on both of the claims, strikes N. 70° W. and dips 35° NE. It varies from 3 to 8 feet in width and follows the general trend of the inclosing limestone. It is traversed by slipping planes, showing that a deformation of the vein has taken place since its deposition. Both in the vein and in the country rock sulphide minerals are finely disseminated and occur in small masses throughout the vein. The minerals observed are free gold, pyrite, chalcopyrite, tetrahedrite, galena, and sphalerite, and at the surface malachite, azurite, and limonite are present.

Amazon claim.—The Amazon claim is located about 1 mile north of Dolomi and west of John Creek (fig. 18). The country rock is a calc schist striking N. 85° E. with a dip of 50° NW. The deposit is a breccia vein from 5 to 10 feet in width, which is parallel to the

bedding plane. The developments consist of an inclined shaft 125 feet deep and at a point 50 feet below the surface a drift extended 30 feet to each side. The ore is of relatively low grade.

Salmon claim.—This claim is located on the west side of John Creek one-fourth mile north of Dolomi (fig. 18). The ore at this point is inclosed in a greenstone schist and consists of a breccia vein averaging 5 to 15 feet in width, striking N. 80° W. and exposed for 300 feet in length by open cuts and shallow pits. The surface exposures of this deposit are much oxidized, the original sulphide minerals being pyrite and chalcopyrite. Material from the oxidized portion subjected to pan tests yielded colors of gold.

Beauty claims.—The Beauty group of two claims lies one-half mile north of Dolomi on the east side of John Creek, the lower claim crossing to the west side of the creek (see fig. 18). A quartz vein 4 to 6 feet wide striking N. 20° E. and dipping 45° SE. constitutes the ore body. This traverses a limestone belt striking N. 30° W. and has been traced for nearly 1,000 feet, being exposed on claim No. 2 by two inclined shafts 50 feet and 60 feet in depth and on claim No. 1 by a 15-foot shaft. On the east side of the latter claim another vein deposit 2 feet in width parallels the bedding plane of the limestone, but has only been exposed by an open cut. The minerals contained are tetrahedrite, chalcopyrite, and pyrite, with small amounts of malachite and azurite exposed on the surface.

Fortune claims.—The Fortune claims begin 100 yards below the mouth of James Lake and extend northwest along the southwest shore of the lake. The country rock is a graphitic schist with included bands of blue limestone. The ore body is a lode deposit striking N. 60° W. and dipping 25° SE. and is 10 feet or more in width including quartz veins from 1 foot to 2 feet in width. Slipping planes are of common occurrence throughout the deposit, and in places it is much fractured. Chalcopyrite and pyrite are the principal minerals that occur. The developments consist of shallow shafts and open cuts and do not exceed in amount the annual assessment requirements.

Alpha group.—The Alpha claims, three in number, are located between 300 and 400 feet elevation on the mountain 1½ miles from Dolomi and half a mile east of James Lake (see fig. 18). The principal ore body developed consists of a vein deposit 5 feet in width, which has been traced for nearly 2,000 feet in length. The rock formation consists of a banded limestone, in places schistose and much folded, striking N. 80° W. The vein has a north and south strike and dips 45° W. and contains pyrite and chalcopyrite with small values in gold. The development work consists of open cuts and a shaft 35 feet deep.

Golden Fleece group.—The Golden Fleece property, which represents one of the earliest locations in the region, lies on the north end

of James Lake 2 miles from tide water (see fig. 18). A 5-st mill was erected on the property in 1901 and a tramway built the lower end of the lake to the wharf at Dolomi. The min velopments, which were actively advanced in 1901–2, consist of long tunnels, each 200 feet in length, and from them stopes winzes have been sunk on the ore body. Early in 1905 work on property was suspended and since that time no attempt has made to operate this mine.

The ore deposits are irregular lenses slightly cutting the bed planes of the inclosing limestone and varying from a fraction foot to 8 feet or more in width. The strike of these irregular posits is northeasterly, the dip being 40° SE. A peculiar and vantageous feature of this mine is the occurrence of several limes caverns which in places follow the mineral deposit. Crosscutt both the limestone and the ore bodies are diabase dikes which of more recent intrusion than the ore deposit. The ore consists free gold with tetrahedrite and pyrite, the grade on a whole be moderate.

PROSPECTS ON SOUTH SIDE OF NORTH ARM.

On the south side of North Arm several groups of claims ha been located on the mountain slope 1 to 2 miles from the shore, with the exception of annual assessment work the developments ha been slight (see fig. 7).

The Westlake group consists of three claims, the Little Annis, t Blue Bird, and the Homestake, located in 1901. On the Little An claim, at 1,200 feet elevation, quartz stringer veins occur in gran near its contact with a schist belt and have been exposed near contact by several open cuts. The veins strike N. 30° E. and dip 7 SE.; they are variable in width, contain pyrite in small amounts, a are reported to carry low values in gold. At 1,500 feet elevation, the Blue Bird claim, which has been relocated and is now called t Sleepy Eye claim, a shaft 40 feet deep has been sunk on a bedded ve in mineralized schist, striking N. 60° W. and dipping 55° SW. T metallic minerals are galena, zinc blende, pyrite, and occasional par cles of free gold, in a gangue of quartz and graphite. The sch formation is banded and varies from phyllite to green chlorite schi The vein is reported to carry high values in gold and can be trac for a considerable distance. The main quartz vein shows evider of having been fractured and recemented by later quartz fillin The developments on this group of claims, however, have not y progressed sufficiently to expose ore bodies of any extent or gr promise.

Northwest of the Westlake group and nearer the shore is the Ho claim, on which a pyritiferous quartz vein has been discovered f

[illegible]

lowing slipping planes in chlorite schist. The vein is irregular in width and direction and has been investigated by means of a tunnel at 450 feet elevation and about 80 feet in length. Not far from the tunnel a large intrusive granite mass invades the chlorite schist. These claims were visited and described by Mr. Brooks in 1901, and but little work has been accomplished on them since that time.

GRAVINA ISLAND.

GENERAL DESCRIPTION.

The only gold deposits so far discovered on Gravina Island are along its eastern shore opposite Pennock Island. This portion is made up of the greenstone schists with interstratified slate beds striking N. 50° W. and dipping 60° NE. These are intruded by occasional dikes of diabase striking approximately north and south, which crosscut the ore deposits. The ore bodies are both vein deposits and lode deposits, the latter being the most important. The lodes consist of an impregnation of sulphide minerals and fillings of quartz in the form of veinlets along beds of altered greenstone schist. This character of mineralization extends from 5 to 50 feet in width and is often traceable for a few thousand feet along the trend of the schist. Such lodes may be readily recognized on the surface by the bleached appearance of the rocks caused in part by the decomposition of the sulphide minerals. The principal metallic mineral is pyrite, disseminated in the form of small, bright cubes and contained in both the quartz veinlets and the schist in amounts varying from 2 to 4 per cent. The presence of slipping planes and narrow seams, usually transverse to the schistosity, which are often filled with quartz containing the sulphide minerals galena and sphalerite, indicates an injection of mineralizing solutions subsequent to the main period of ore deposition. Gold is also present in these later veins in small visible particles.

GOLDSTREAM GROUP.

Situation and development.—The Goldstream group of six claims, the property of the Irving Consolidated Mining Company, is situated close to tide water on the east side of Gravina Island 3 miles south of Ketchikan. The presence of mineral deposits outcropping along the shore at this locality has been known since 1897, and various attempts have been made to develop them, but with little success. The principal work was done in 1903, when a 5-stamp mill was installed, a shaft was sunk, and drifts were extended along the ore body. Small developments were accomplished the following two years, and the values recovered from the ore mined and treated in the stamp mill are reported to have defrayed all development expenses. In 1906

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the Irving Consolidated Mining Company was organized and larger operations were begun. The present developments consist of a shaft 115 feet in depth, from which two levels 50 and 100 feet below the surface have been extended and about 400 feet of drifting and cross-cutting has been accomplished. From the stopes in the ore body 3,000 tons of ore are reported to have been mined. At other points on each of the two adjoining claims to the southeast belonging to the same company a 50-foot shaft has been sunk and open cuts and trenches have been made along the ore bodies. Besides the 5-stamp mill a wharf has been built and several buildings erected.

Ore bodies.—Two lode deposits occur at this mine, both striking parallel with the schistosity of the inclosing rock and being separated by a belt of unmineralized schist 90 feet in width. The country rock is a schist of variable character, made up of both igneous and sedimentary material, the predominant varieties being chlorite, talc, and quartz-sericite schist. The main deposit, on which the principal developments have been advanced, has a width of 4 to 8 feet and is traceable 1,000 feet or more in length. Though the lodes are mineralized throughout, the values are confined to an ore shoot pitching 60° SE. in the lode exposed at the top of the shaft. This is exposed in both the 50- and 100-foot levels for 60 to 80 feet in length, and from it a large portion of the ore has been mined. It is reported that late in 1906 another ore shoot had been opened on the 100-foot level by a drift extending northwest from the shaft. The principal minerals contained in the ore from this deposit are pyrite, chalcopyrite, galena, sphalerite, and some arsenopyrite. The gold occurs native, associated with the sulphides and quartz seams in small particles, and along slipping planes and cracks in the form of thin flakes. In the mine workings an altered diabase dike several feet wide has been encountered crosscutting the ore body and striking N. 10° W. with a dip of 75° NE. Quartz stringers barren of mineral were observed to intersect this dike, and these and the dike are younger than the general mineralization of the schists and apparently of more recent intrusion than the second period of mineralization represented by the quartz seams carrying galena and sphalerite. On the second lode deposit, 100 feet southwest, is a much wider ore body exposed across a width of 40 feet and for several hundred feet in length. The hanging- and foot-wall sides of this lode are defined by bands of heavily mineralized rock 8 to 14 feet wide, the central portion being composed of but slightly mineralized schist. A 50-foot shaft has been sunk on the foot-wall portion of the lode, but the ore developed carries only small values in gold. The possible continuation of this deposit has also been prospected on the adjoining claim to the southeast by a 50-foot shaft and surface trenches.

HECKMAN GROUP.

The Heckman group consists of five claims which start at a point on the shore 1 mile south of the Goldstream mine and extend northwesterly up the eastern slope of the island. Close to the beach is a 60-foot shaft with drifts 32 feet in length exposing a lode deposit 8 feet in width. At a point half a mile to the northwest a second shaft has been sunk 50 feet on a similar lode deposit, though at this point but a small amount of mineralization was observed. No work has been done on these claims during the last few years.

MOONSHINE GROUP.

The two claims which comprise the Moonshine group are located one-fourth mile south of the Heckman group. The ore bodies on these claims consist of two parallel vein deposits striking northwest, the one 18 feet and the other 6 feet wide, separated by 50 feet. The country rock is made up of black and altered greenstone schist. On the larger vein is an open cut 30 feet long, and on the smaller vein a shaft 12 feet deep has been sunk. No work has been advanced on these deposits during the last few years and the ore is apparently of too low a grade to encourage further developments.

ANNETTE ISLAND.

Annette Island lies just south of Gravina Island and includes an area of 133 square miles. The eastern and central parts of the island are abrupt and mountainous, the highest summit being Mount Tongass, with an elevation of 3,684 feet; the west coast of the island is low and flat and is fringed by dangerous reefs. The only village on the island is the thriving Indian settlement Metlakatla, which is unique in many ways and owes its existence and present prosperity entirely to Mr. William Duncan, whose active life has all been practically devoted to the uplifting and education of this tribe of Indians. The results he has attained and the high plane of civilization to which he has brought these untaught Indians are most creditable, and, as an example of devotion and self-sacrifice, his work will ever remain an unparalleled achievement in the annals of the pioneer life of Alaska.

By act of Congress Annette Island was reserved for the exclusive use of the Indians under Mr. Duncan. At the time when this act was passed little was known of the mineral resources of this country, although prospectors had already located claims on the east side of this island and developed them to some extent. On the passage of this law these prospectors were banished from the island and further prospecting prohibited, the object in view being to isolate the Indians and remove them from the influence of the whites as much as possible. In the course of years the Indians have shown themselves independent and capable to cope with the white men in their chosen

field of activity. With the exception of Metlakatla, the island is uninhabited and is benefiting neither Indian nor white man. In his report on this district Mr. Brooks[a] presented a broad view of the case and suggested that the eastern mountainous half of the island be opened to prospectors and mining men, to whom much of the development of this region is due. The Indians by nature do not take kindly to prospecting and mining and have given no indication that they will ever use in any way the eastern half of the island, which has little or no value from an agricultural standpoint. To release the land a special act of Congress will be necessary, and even then it is not certain that mineral deposits of great value will be discovered. However, abundant evidence of mineralization and small deposits of high-grade ore were observed on the island by the writers.

The geology of the island is represented in a general way on the map (Pl. II). The central portion is composed of intrusive granitic masses and is surrounded by Paleozoic limestones, schists, and slates, and along the eastern shore the latter are overlain by greenstones with interstratified slate beds. Along the southeastern shore, both in the granite and the schists, are vein deposits in which pyrite, chalcopyrite, and some galena were noted. Many of these were located and prospected in former years. Vein deposits and ore pockets occurring in a limestone belt were developed to considerable extent at a point 2 miles from tide water on the south side of a lake on the east side of the island. These veins are small and of no great extent, being less than a foot in width and less than 100 feet in length. Several of these deposits, some of which are mere pockets, have been exposed by open cuts. They contain much tetrahedrite and some chalcopyrite, and are said to carry high values in both gold and silver. On the east side of this lake is a band of mineralized schist containing chalcopyrite and pyrite, which, however, has not been developed and is said to carry low values in copper and gold.

North of these deposits, about a mile from tide water, quartz veins were observed in the schist adjacent to the granite and in a few instances in the granite. These are well defined on the surface and vary from 1 foot to 4 feet in width. They contain practically no sulphide minerals, and are said to carry low values in gold.

Mining developments and prospecting have been at a standstill since this island was made an Indian reservation, and the above prospects and deposits, though worthy of further investigation, have been idle.

DALL ISLAND.

General description.—Dall Island is an irregular mountainous land strip, about 40 miles in length, lying southwest of Prince of Wales Island, with summits averaging from 1,500 to 3,000 feet in altitude.

[a] Brooks, A. H., Prof. Paper U. S. Geol. Survey No. 1, 1902, pp. 108–109.

It is made up essentially of schist, limestone, and occasional narrow belts of granite, all of which have a northwesterly trend and traverse the island at an angle to its principal axis. Prospecting has not been vigorous in consequence of its isolated position, and its oceanward coast is known to only a few of the more persistent gold seekers.

Dakoo Harbor prospects.—The principal prospects on Dall Island are located at the south end at Dakoo Harbor, 2 miles northeast of Cape Muzon, on the Elk and Virginia claims. The ore bodies are both auriferous quartz veins and belts of schist impregnated with gold-bearing sulphides. On the Elk group, which is situated only a short distance from tide water, two tunnels have been driven 200 and 265 feet in length, at 80 and 450 feet elevation, respectively. The deposit is exposed only in the upper tunnel and by several open cuts. It consists of a belt of decomposed schist, and across a width of 50 feet or more this is reported to carry sufficient values in gold to make low-grade ore. The Virginia group lies northwest of the Elk at an altitude of 300 feet, 1½ miles from tide water. Bands of mineralized schist also occur on this property, but the principal ore bodies are quartz veins varying from narrow stringers to veins 10 feet in width. They are exposed by two shafts less than 20 feet in depth and by short tunnels located in a narrow creek canyon. The country rock is a weathered amphibole schist interbedded with narrow bands of crystalline limestone. The gold values are associated with pyrite, chalcopyrite, and galena, and are said to be higher than those contained in the Elk lode.

Mount Vesta prospects.—The Mount Vesta group of claims, a property of the Alaska Industrial Company, is located on the northeastern slope of Mount Vesta, about a mile from Mount Vesta Harbor. The mineral occurs in small seams or veinlets a few inches in width and separated by wide areas of crystalline limestone. The ore is of high grade and composed essentially of tetrahedrite (gray copper) and chalcopyrite with galena and sphalerite. The mine workings are situated between 600 and 800 feet in elevation, and consist of open cuts and a tunnel 80 feet in length. Many other prospects have been located along the east coast of Dall Island, though no improvements of importance have been made on them.

BAKER ISLAND.

Baker Island is one of the smaller seaward mountainous land masses off the west coast of Prince of Wales Island and north of Dall Island (see Pl. I). Its western side is composed of a granite belt intruding argillaceous schists, which lie to the east, striking northwesterly and dipping northeast. The rock exposures around the east side of the island are mainly of greenstone lava and tuff beds with some interstratified argillites.

Adjacent to Port Antonio, in the central portion of the island, deposits consisting of small quartz veinlets in the granite and the adjacent schists have been located and prospected to some extent.

The principal prospect is located on the north side of the bay at about 300 feet elevation. Here quartz veinlets carrying some galena, sphalerite, and pyrite inclosed in the argillaceous schists have been exposed by open cuts, and the ore is said to carry high values, though the amount developed is small. Near the entrance to San Antonio Bay several parallel quartz veins are exposed along the shore inclosed in the granite and containing small amounts of pyrite. They have not been developed, and the values contained are said to be low.

WOEWODSKI ISLAND.

General description.—Woewodski Island lies between the south end of Wrangell Narrows and the entrace to Duncan Canal and is separated from Kupreanof Island to the north by Beecher Pass. It is a relatively low-lying land mass from 3 to 4 miles in width and 5½ miles in length, and is heavily timbered to the mountain tops. Geologically the island is traversed by the slate-greenstone belt striking northwest and intruded by diorite batholiths in a small area in the northeast section of the island. A large number of mining claims are located along both the east and west shores of the island and a large amount of development work has been done, though none of the properties have reached the producing stage. The ore bodies are principally vein deposits containing essentially gold values and inclosed in the slate greenstone country rock.

Hattie group.—The Hattie group of claims, the property of the Olympic Mining Company, is situated close to tide water on the southwest side of Woewodski Island (see fig. 20). The claims were first located in 1900, and in 1901 active developments began and progressed until the end of 1903. In 1904 operations were suspended and the property was idle until the summer of 1907, when small developments were again in progress. The surface developments consist of a wharf, connected by a tramway 1,000 feet long with the mine workings, and various mine buildings.

At the mine a 360-foot tunnel has been driven in a northeasterly direction, and at a point 60 feet from its mouth a shaft has been sunk 135 feet in depth from the tunnel level, and from this shaft two levels have been extended at depths of 62 and 134 feet. At the time of the writer's visit the shaft was filled with water, and observations were necessarily confined to the tunnel and surface exposures of the ore bodies.

The country rock is essentially an altered greenstone, in places schistose, striking northwest. The ore bodies are vein deposits filling fissures and breccia veins along planes of brecciation in the country

rock, and in places both fissure and breccia veins occur together. Several deposits of this character have been exposed in the mine workings and along the surface, the largest being the Hattie vein, varying from 5 to 20 feet in width, and traceable for several hundred feet in length. The vein has a northeast strike and dips 80° SE., but in places it stands nearly vertical. As a whole it is apparently of too low grade to make ore, but in it are shoots of ore pitch-

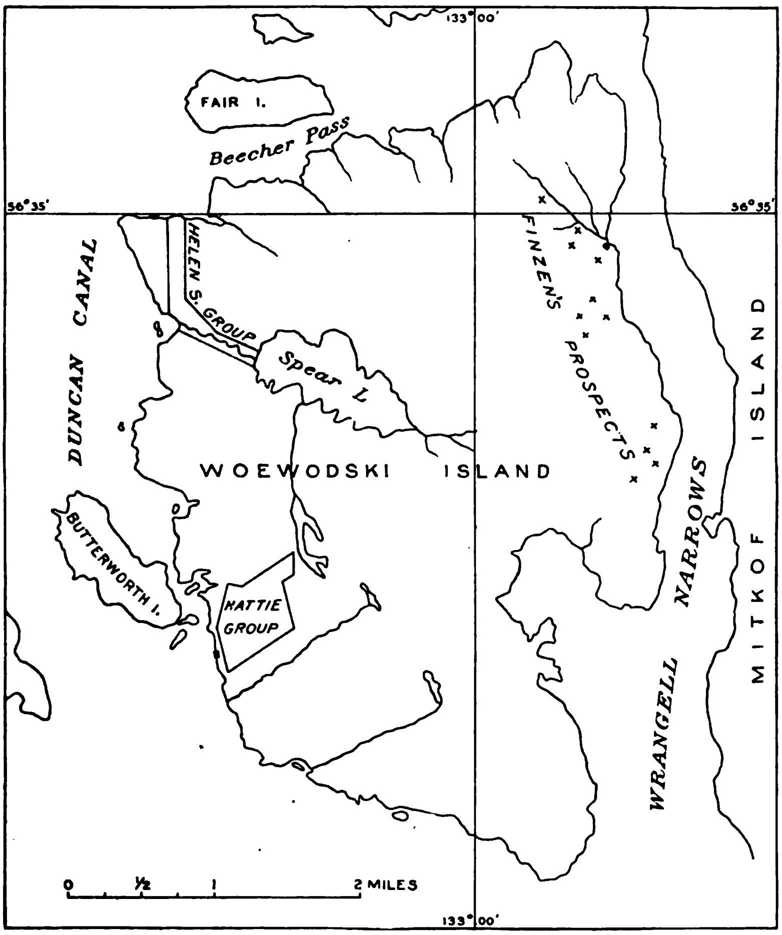

FIG. 20.—Sketch map of Woewodski Island, showing positions of mining claims.

ing southwest in which good values are reported. Fault planes, indicated by gangue seams, were observed striking north and south, but they do not appear to have displaced the vein to any extent. The vein material is principally quartz surrounding large masses of altered greenstone, which is also slightly mineralized. The ore minerals, which constitute from 1 to 3 per cent of the vein filling, are

pyrite, with chalcopyrite, galena, and some sphalerite. The values contained are essentially in gold, with some silver and copper.

Helen S. group.—The claims belonging to the Helen S. group are situated 2¼ miles northwest of the Hattie group on the northwest end of the island. The claims were located by the Olympic Mining Company in 1902, and active developments were advanced in 1903 and to some extent in 1904. In 1905 and 1906 the property was idle, and not until the summer of 1907 was it reported that small developments had again begun. A 20-stamp mill and compressor plant have been erected on the property, but, except a small run for test purposes, this machinery has remained idle. At a point 600 feet from tide water a shaft 100 feet deep has been sunk, and at this level 650 feet of drifting and crosscutting has been extended; 400 feet to the north a second shaft has been started.

The country rock exposed along the shore and up the creek bottom is principally greenstone schist with some black slate bands interstratified striking north and south with a dip of 70° E. Open cuts have exposed several quartz veins and stringers interbedded and branching in various directions along jointing planes. At 40 feet elevation a quartz vein 4 feet wide containing galena, sphalerite, and pyrite crosses the creek and is parallel to the schistosity of the inclosing greenstone. Just above this, at an altitude of 50 feet, is a 2-foot vein striking N. 85° E., at right angles to the former, and dipping 80° N. It has been developed by a 15-foot shaft and open cut. The veins of this system, though usually small, are reported to contain higher values than those that parallel the structure of the inclosing rocks. The principal deposit on which the shaft has been sunk and the drifts extended consists of a mineralized belt of schist striking north and south and dipping 50° E. and intersected across a width of 5 to 15 feet by a network of quartz and calcite stringers, in places having a banded flinty character. This has been traced several hundred feet in length, and the included rock as well as the stringers contain pyrite with some galena and sphalerite in small masses and disseminated particles varying from 2 to 4 per cent in amount. The gold values are combined principally with the pyrite, and the tests made yielded but a small per cent of free-milling gold, most of the values being contained in the concentrates.

WORONKOFSKI ISLAND.

General description.—Woronkofski Island occupies an area of about 25 square miles in Stikine Strait and lies just west of the town of Wrangell. It is heavily timbered to its mountain summits, which reach 1,500 feet in altitude. The rock exposures around its northern and eastern shore are argillites and schists. To the southwest these are intruded by a wide mass of granite, which occupies the western

portion of the island. The ore occurrence on this island is of interest because the deposits are included in the granite intrusive.

Elephant Nose prospects.—The principal prospects in the vicinity of Elephant Nose are the Exchange group of several claims located in 1900. The mine workings are located near tide water in a cove just west of Elephant Nose. Here a quartz vein 12 to 15 feet wide is exposed by surface cuts and is undercut 25 feet in depth by a tunnel 45 feet long. This vein deposit crosscuts the granite striking north and south and dipping 30° W., and includes small masses of the granite. The minerals contained are essentially pyrite and the vein is said to carry moderate values in gold.

SMEATON BAY PROSPECTS.

The prospects near Smeaton Bay are located on the mainland shore 2 miles south of Roe Point in Behm Canal. The mineral deposits at this point are situated within the metamorphosed schist-gneiss belt which flanks the Coast Range granite on the west and strikes ordinarily parallel to the shore line and dips at steep angles northeast or southwest. In the vicinity of this claim calc-mica schist and quartz-mica schist predominate, while farther north typical gneiss occurs. Dikes and bosses of granite intrude the complex at many points and are of the general Coast Range type of granodiorite. Two hundred paces south of the tunnel two such dikes of granodiorite 10 and 20 feet wide invade the schists and may bear a possible genetic relation to the ore body. The ore body consists of a mineralized belt or bands of calc-mica schist and is characterized by a well-marked slipping plane with gouge above its foot wall. The sulphide ore consists of pyrite, pyrrhotite, and chalcopyrite and is said to carry low values in gold and silver. Quartz, muscovite, and calcite constitute the gangue and are often stained brown and red by ferruginous weathering products. The claim is well located in respect to timber and transportation, and, although the values are not sufficiently high to warrant predictions of future production, the location near the Coast Range contact is unique for this region. This deposit was discovered in 1898 and has thus far been developed by 100 feet of tunneling and crosscutting, the mouth of the tunnel being located about 10 feet above the high-tide water mark. Only the annual assessment work has been done.

UNUK RIVER PROSPECTS.

Unuk River, one of the few large streams in southeastern Alaska, is very difficult to navigate even in a small boat. It rises about 55 miles from the head of Burroughs Bay, in Behm Canal, and traverses the entire granite portion of the eastern Coast Range. A low divide connects its head with a branch of Iskut River and thus serves as an east entrance way into the interior of British Columbia. The upper

25 or 30 miles of the river drain the schist-argillite belt lying east of the Coast Range granite, which is characterized along its entire extent from British Columbia to the Skagway district by good silver and gold bearing veins. At the head of Portland Canal, on several of the Stikine River tributaries, especially Clearwater River, in the Atlin district and still farther north, this belt is known to carry both placer deposits and quartz ore bodies. It has long been known that similar deposits occur in the Unuk River region, and recently a company began the construction of a wagon road from salt water along the northwest bank of Unuk River to a group of claims 42 miles inland across the boundary in British Columbia territory. Both placer and quartz claims have been located and will probably become ore producers as development proceeds. Now that access to

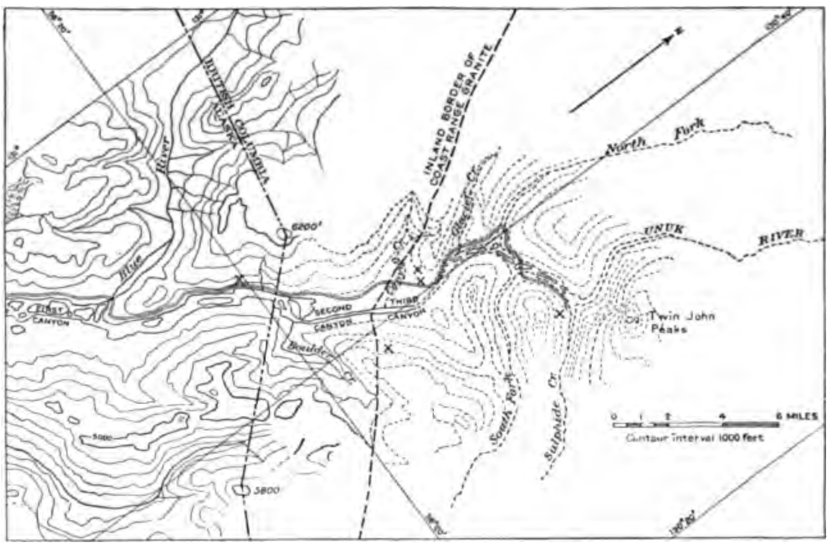

FIG. 21.—Sketch map showing positions of prospects on Unuk River and near the International boundary line.

the region has been made possible by the road, it is to be expected that during the coming season many prospectors will avail themselves of the opportunity to visit it and give it a thorough test. This field is not described in detail, because its mineralized belt, like that lying inland from the head of Portland Canal, appears to be entirely on the Canadian side of the boundary (see Pl. II and fig. 21).[a]

SILVER, LEAD, AND ZINC MINES.

GENERAL DESCRIPTION.

Deposits of silver, lead, and zinc ores are not plentiful in either the Ketchikan or the Wrangell districts. In only three localities are such being developed, and the ore production from these has been

[a] Wright, F. E., Unuk River district: Summary Rept. Canadian Geol. Survey (for 1905) 1906, pp. 46-53.

slight. Silver occurs in its sulphide form, usually associated with galena, and many specimens assay from 16 to 20 ounces per ton in silver.[a] It is also present in amounts varying from one-fifth ounce to 3 ounces per ton in the copper ores. The total production of silver in 1906 from these ores was $18,000. In the gold ores its content is more variable and is dependent upon the amount of gold present, the ratio being approximately 2 ounces of silver to 1 ounce of gold. Lead occurs entirely in the form of galena and has been mined in small quantities from the properties on Coronation Island and the Moonshine property in Cholmondeley Sound. It is also present in the gold ores and rarely in the copper ores, but in such ores the lead content is of no value. Zinc is not known to occur in this region in commercially valuable amounts, and, though present to the amount of 5 to 10 per cent in some of the ores, its content is in most cases a detriment as it renders smelter treatment more difficult.

SOUTH ARM OF CHOLMONDELEY SOUND.

MOONSHINE GROUP.

Situation and development.—This property includes several claims and lies west of the South Arm of Cholmondeley Sound, about 1½ miles from tide water on the crest of the mountain ridge, at an elevation between 2,000 feet and 2,400 feet (see fig. 16). In 1906 these claims were located as the Moonshine group, and early in the spring were sold to the Alaska Galena Company. Developments were begun by this company in August, 1906, and in November were suspended for the winter. During 1907 operations were in progress from May until November.

The ore body has been developed by a shaft on the crest of the ridge 100 feet deep, and 550 feet to the west by a drift tunnel 200 feet in length, which is being driven to connect with the shaft at a point 225 feet below the surface. Besides the mine development considerable work has been expended on a horse trail from the beach to the mine, a distance of 2 miles.

Ore body.—The Moonshine vein, as it is called, occupies a well-defined fissure, cutting obliquely across limestone and schist country rock and traversing the top of the mountain ridge. Where it cross-cuts the limestone it is apparently a replacement deposit, varying from a few inches to several feet in width and carrying considerable galena associated with quartz, siderite, and calcite, though where the schist forms the inclosing walls the vein is smaller and is in many places represented by a narrow gouge seam. The country rock strikes nearly east and west and dips north at steep angles, whereas the vein strikes N. 65° W. and has a vertical dip. In this vein deposit the mineral occurs irregularly, the ore being found in small scattered

[a] See p. 88.

masses or bunches. Besides the galena a small amount of sphalerite and chalcopyrite is present, and silver values amounting to many ounces per ton occur in the ore. Very little surface alteration or secondary enrichment was observed, and where present it extends but a few feet in depth. Diabase dikes from 1 foot to 6 feet in width crosscut both the country rock and the ore body.

GROUNDHOG AND GLACIER BASINS.

General description.—These groups of claims are located on the mainland about 14 miles due west of Wrangell and are reached by trails starting from Eastern Passage and leading around Mill Lake, which occupies a basin 3 miles long, to Groundhog and Glacier basins, about 8 miles from tide water (see Pl. III and fig. 22). The ore

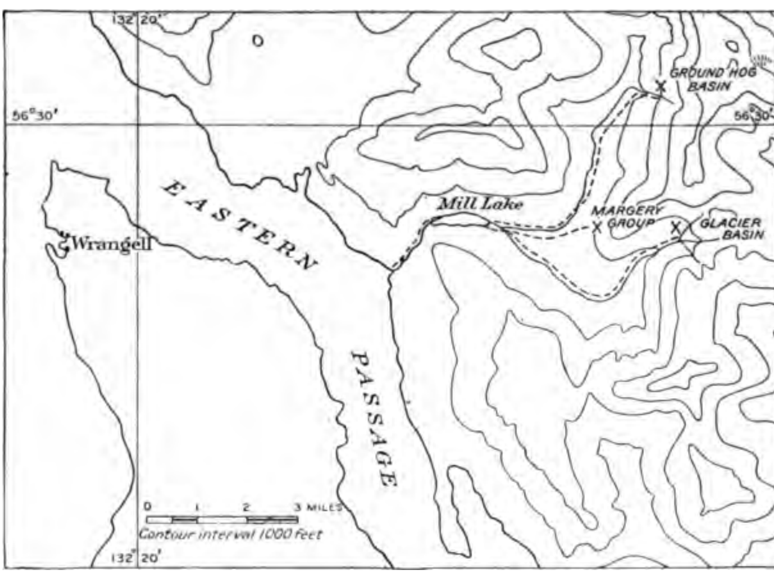

FIG. 22.—Sketch map showing location of Groundhog Basin and Glacier Basin prospects.

bodies occur in a slate-schist belt, which is included between the main Coast Range granite mass and an outlying granite belt averaging 1 to 3 miles in width and is intrusive approximately parallel to the bedding planes of the adjacent rocks. The total thickness of the included slate-schist belt is about 6,000 feet. Its N. 35° W. course is indicated on the general map, the dip varying from 30° to 60° NE., into the mountains. The entire belt is considerably mineralized and may be recognized by its red color, which is due to the oxidation of the sulphide minerals. This belt is penetrated by parallel and cross-cutting acidic porphyry and aplitic dikes, along which the ore deposits are usually found. These dikes are younger than the granite and older than the basaltic dikes that occur here. Near the Coast Range

granite contact the metamorphism of the schists is more intense than farther west, and at these points gneissoid rocks prevail. The degree of mineralization, however, is greater, and the aplitic and porphyry dikes are more numerous nearer the western intrusive granite. The claims which have been located in this belt are mostly above timber line and not easily accessible at present, as transportation facilities are lacking.

Glacier Basin group.—Glacier Basin, a rock-rimmed basin produced by glacial erosion (fig. 22), standing 2,100 feet above sea level, is reached by a trail 7 miles in length from Mill Lake. At the head of the basin Nelson Glacier still exists as evidence of the former ice sheet and is slowly retreating up the mountain cliffs. The claims of this group are located on the north side of the basin within the slate-schist belt and have been developed chiefly by two short drift tunnels and surface cuts. The rocks are practically bare, and the veins can be traced directly up the mountain slopes for long distances, varying from 4 to 20 feet in width, occurring unusually near or in the intrusive aplitic or porphyry dikes. The veins are heavily mineralized with galena, zinc blende, pyrite, and chalcopyrite. The values are in gold and silver and are only of fair average. The transportation difficulties are at present a very important drawback to these claims from a mining standpoint.

Georgia group.—The Georgia group of two claims is located on the south side of Glacier Basin on a vein parallel to the schistosity of the inclosing rock and similar in character to the Glacier Basin deposits though not so large. The developments on this group have been very slight.

Groundhog Basin group.—This property is located northwest of Glacier Basin in the same mineral belt and is reached by trail from Mill Lake about 4 miles in length (see fig. 22). The actual workings are located at 2,100 feet elevation on the north side of a steep gulch tributary to the main valley, at which point they can be observed at the contacts of the intrusive porphyry dikes in the slate-schist belt. Surface oxidation has colored the veins dark red, so that they are visible from long distances and can be easily traced. At the Groundhog Basin group the vein is 6 feet and more in width, being heavily mineralized with galena, zinc blende, and pyrite. It has been exploited by two open cuts and short tunnels. The assay values are reported to be of only fair average. The persistence of these veins along the strike argues well for their continuation in depth.

Margery group.—The Margery group is located at an elevation of 1,500 feet on the west slope of the mountain spur which separates Glacier Basin and Groundhog Basin valleys and is more favorably situated for mining than most of the properties in this area (see fig. 22). At one point is a lode deposit consisting of quartz stringers

1 foot to 5 feet wide following a definite zone parallel to the inclosing schist and near the contact of a large intrusive granite mass. Several open cuts and short tunnels expose this lode along its strike. To the northeast of this on the same claim is an open cut exposing a 12-foot vein rich in galena and similar in character to the other veins in this area. Mineralization is usually heavy, especially in galena, besides which sphalerite, chalcopyrite, native silver, cerusite, and limonite occur in varying amounts. The values are reported good, especially in silver.

CORONATION ISLAND PROSPECTS.

General description.—Coronation Island, which includes an area of 30 square miles, is one of the seaward islands which lies at the entrance to Sumner Strait 35 miles southwest of Shakan. Geographically it is made up of Paleozoic limestone and schist, which are intruded by a granite mass (see Pl. I). Discoveries of galena on this island were made in 1900 by sailors who were driven into Egg Harbor, on the northwest end, by a storm. These men found galena float on the west shore of the harbor and at points from 700 to 1,000 feet elevation deposits of the ore in place. They prospected these to some extent and in 1902 the Coronation Island Mining Company was formed, which has continued operations in a small way since that time. Three tunnels have been driven on three separate ore bodies: No. 1 at 980 feet elevation and 162 feet long; No. 2 at 860 feet elevation and 510 feet in length; No. 3 at 700 feet elevation and 110 feet long. Over 100 tons of the ore have been mined, sacked, and shipped to the smelter from this locality.

Ore bodies.—The ore deposits are narrow, irregular masses of galena ore in a limestone country rock, and few exceed 20 feet in their greatest dimension, but at the lowest tunnel an irregular vein deposit containing small pockets of galena ore is exposed. At tunnel No. 1 the ore body, which is exposed at the entrance, is 8 feet wide, 8 feet by 12 feet in length, and about 18 feet in depth, the continuation of the tunnel exposing practically no ore. No. 2 tunnel has been driven along slipping planes in the limestone having a general N. 80° W. strike with nearly vertical dip. At a point 296 feet from its mouth there is a short crosscut to the north, from which a 10-foot raise has been extended along a galena body 3 feet wide by 15 feet in length and depth, following along one of the slipping planes. Just beyond this point a second crosscut has been driven, in which an altered diabase dike 5 feet in width was observed following the same trend of the slipping planes, but having no apparent connection with the ore deposits. The ore body shown in the lowest or No. 3 tunnel varies from 1 foot to 4 feet in width and has been followed for 100 feet in length. Here the hanging wall is well de-

fined by a slipping plane, but the foot wall often merges into the limestone country rock and is but poorly defined. The ore occurs in small scattered pockets, the largest having been opened by a raise 60 feet from the tunnel entrance. Besides galena the sulphides, tetrahedrite and sphalerite are present in the ores, and near the surface limonite, cerusite, and smithsonite were noted.

BUILDING STONES.

GENERAL STATEMENT.

The recent developments and increasing production from marble quarries on Prince of Wales Island have shown that building stone is an important resource of this region. Other structural materials, such as granite, gypsum, cement, and clay deposits, are also widely distributed along this coast. Little consideration has been given to these nonmetallic products of this Territory, and the increasing use of such materials in the United States demands a more thorough investigation of these resources. Though distant from the market, many large deposits of structural material are well located for quarrying and for transportation by water.

The only stones of value in southeastern Alaska, so far as known, are the marbles and granites. The market for these stones is in the cities along the Pacific coast of the United States, 600 to 1,000 miles distant. They must, therefore, be of more than ordinary quality to bear the expense of freight, as good stone is found in the vicintiy of most large cities, and builders, as a rule, prefer to use a known rock which is near at hand and can be readily obtained.

To place the Alaskan product on the market, it will be necessary to establish supply stations, with dressing and cutting plants, in the larger seaboard cities, where cheaper and more efficient labor may be obtained than in Alaska. To supply these points, the rough granite and marble could be transported in hulks or barges carrying several thousand tons at a low freight rate, and the necessity of careful handling during the shipment would be avoided.

To determine the structural value of a building stone, microscopical, chemical, and physical tests should be made. This is more necessary for marbles and cement stone than for granite. Most university laboratories are equipped for such tests and will make them at a reasonable cost.

MARBLE.

DISTRIBUTION.

Beds of marble are known to occur at points along the mainland portion of the Ketchikan and Wrangell districts as well as on many of the islands. They are invariably at or near the contact of an in-

trusive belt of granodiorite, which has been one of the principal factors in metamorphosing the original limestone beds to their present crystalline or marbleized condition. The age of the limestone beds is Paleozoic, and only in a few places could a more definite determination be made. The largest deposits of marble under development are at the northwest end of Prince of Wales Island near Shakan and on Ham Island south of Wrangell.

NECESSARY QUALITIES.

Commercially marble includes all limestone rocks susceptible of receiving a good polish and suitable for ornamental work. It is not a simple matter to judge the value of a marble deposit, and this can not be done from mere tests of small samples, which, nevertheless, may often give significant results. Some of the more important factors governing the value of a body of marble are the quality and soundness of the stone as a whole, extent of the deposit, absence of fractures or joint planes, color, lack of objectionable impurities, such as silica, pyrite, and bitumen, facility of extraction, and location of the deposit relative to the market and transportation.

COMPETITIVE DISTRICTS.

Most of the marble used in the western cities for monumental and interior decorative purposes is furnished by eastern dealers and must be shipped across the continent. This is mainly the product of the Vermont and Tennessee quarries or is imported from Italy. Stevens County is the only producing locality in the State of Washington; there are none in Oregon, and but two of importance, the Inyo and Columbia quarries, in California. The total value of the marble production for 1905 from these localities was less than $150,000. This product is sold in a rough state at $1 to $2 per cubic foot, and dressed for ornamental or monumental purposes at $2 to $8 per cubic foot. Cut in slabs 1 inch to 2 inches thick and polished on one side, the retail price varied from $0.50 to $1.50 per square foot. The eastern and foreign marbles sold for higher prices.

DESCRIPTION OF LOCALITIES OF OCCURRENCE.

PRINCE OF WALES ISLAND.

ALASKA MARBLE COMPANY.

Situation and development.—The properties of the Alaska Marble Company are situated on Marble Creek a few miles north of Shakan, bordering the coast for 2 miles in length and over half a mile in width (see fig. 23). They are located upon a belt of Devonian lime-

stone about 3,000 feet in width flanking the west side of an intrusive granite mass, which forms the low mountain ridge to the east and which is evidently the direct cause of the alteration of the limestone to marble. This deposit was first discovered in 1896 and finally located in 1905, the first work being done along the exposures in the creek bed one-half mile from the shore. From 1900 to 1904 prospecting was extended up the hillsides and drill holes sunk to ascertain the quality of the product in depth. Early in 1904 the Alaska Marble Company was incorporated and developments on a large scale were

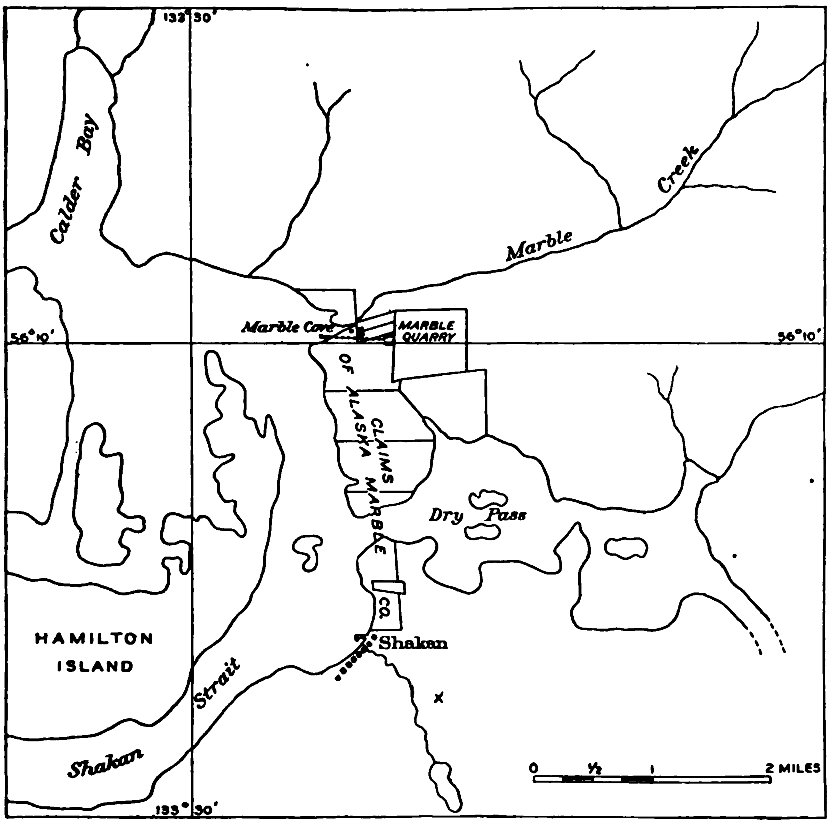

FIG. 23.—Sketch map showing marble quarry and locations of Alaska Marble Company.

immediately begun. At present the plant consists of a wharf equipped with derricks, a gravity railroad to the quarry 3,200 feet in length, necessary channeling and gadding machines, and various buildings. At the quarry, located on the south side of Marble Creek at an elevation of 100 feet, an area 100 feet by 200 feet has been stripped and quarried to an average depth of 60 feet measured on the mountain side (Pl. XII, *A*). A test shipment of 100 tons was made in 1902, but actual production did not begin until early in 1906. The

marble is now being placed on the market in the cities along the Pacific coast. The manufacturing plant of the company is located at Tacoma, Wash.

The marble deposit.—The extent of the marble deposit at this locality has been investigated at a number of points on the surface by open cuts and trenches and in depth by 18 drill holes and at all of these places marble usually of good quality is exposed. As above noted, the marble belt is approximately 3,000 feet in width striking in a northwesterly direction and dipping to the southwest. It is limited on the northeast by an intrusive granite mass and on the southwest by the shore line. To the south it crosses the entrance to Dry Pass, but just back of Shakan it is cut off by a granite mass, while to the northwest it extends into the channel and reappears at the entrance to Calder Bay, extending northward and overlying beds of conglomerate. Along the shore exposures and at the quarry small dikes of diabase, striking northeasterly and much altered and faulted, were observed intersecting the marble beds. Apparently these dikes antedate the metamorphism of the limestone and therefore the intrusion of the granite. They are, however, but a foot or two in width and not sufficiently numerous to affect the value or expense of quarrying the marble. In the present opening at the quarry only one dike is exposed. Both surface cracks and slipping planes are present in the surface exposures of the marble, but in depth these are less numerous and will not materially interfere with quarrying (see Pl. XII, *B*).

Three distinct varieties of marble are found—pure white, blue-veined with white background, and light blue, often having a mottled appearance. The pure white, which has a finely crystalline texture, is the most valuable. All of the marble is free from silica and flint beds common in most quarries, and though thin seams of pyrite were observed they do not occur in a quantity detrimental to the stone. The following chemical analysis of the white marble was made by E. F. Lass for the Alaska Marble Company:

Chemical analysis of white marble from Marble Creek, Prince of Wales Island, Alaska.

Insoluble matter	0
Oxide of iron (Fe_2O_3)	Slight trace.
Sulphuric anhydride (SO_3)	Trace.
Lime (CaO)	55.59
Magnesia (MgO)	.30
Carbon dioxide (CO_2)	43.67
Undetermined	.44
Total	100.00
Calcium carbonate ($CaCO_3$)	99.26

A. MARBLE BLOCKS READY FOR SHIPMENT, QUARRIED FROM MARBLE CREEK DEPOSITS.

B. MARBLE QUARRY WORKINGS OF THE ALASKA MARBLE COMPANY, 3 MILES NORTH OF SHAKAN, ON PRINCE OF WALES ISLAND.

A qualitative test for magnesia in a sample collected by the writers was made by Dr. George Steiger, of the United States Geological Survey, who reports a content of less than 1 per cent.

To determine the crushing strength of the stone the Alaska Marble Company submitted samples to N. H. Winchell, State geologist of Minnesota, who reports an average strength of 10,521 pounds per square inch, a strength ample for all building purposes. Though not equal to the best Italian grades, this marble is better than most American marbles, and in the market will compete on at least equal terms with the product of Vermont, Georgia, and Tennessee.

Method of quarrying.—At the quarry it was first necessary to remove the uppermost layers of the more or less fractured marble. This was done by channeling machines, a method which is preferable to blasting, as it does not injure the massive rock in depth. The machine used is mounted with " donkey " engine on a truck and cuts a channel 2 inches in width at a rate of 7 to 8 square feet per hour. These channels are extended to a depth of 4 feet and are made at intervals of 4 or 6 feet in one direction and at intervals of 6 feet at right angles so as to form blocks 4 to 6 feet by 6 feet in surface area and 4 feet in depth. These blocks are undercut by gadding machines, in which a drill is set so as to drill a series of holes under the block, and in these holes wedges are driven and the block is freed from its base. It is then lifted by a derrick to the car on which it is carried to the wharf. The blocks contain from 96 to 144 cubic feet of marble and weigh from 7½ to 11 tons each, the dimensions depending on the handling capacity of the machinery (Pl. XII, *A*). The larger part of the marble product is shipped in the rough state to a sawing and polishing plant at Tacoma, where it is prepared for the market. Small shipments have also been made to Chicago, Milwaukee, St. Louis, Cincinnati, and other points for trial tests.

EL CAPITAN MARBLE COMPANY.

The property of the El Capitan Marble Company is situated on the eastern side of a low mountain range 5 miles due east of the Alaska Marble Company's quarry and on the north side of Dry Pass. These locations, including ten claims, were first made in 1901 and were sold to the El Capitan Marble Company in 1903. Except for a small amount of assessment work, operations were not begun until April, 1904. During that year a quarry consisting of a pit 12 feet deep was opened on a marble deposit close to tide water, a channeling and gadding machine was installed, and a cutting plant operated by steam power was erected. Some marble was quarried and shipped to Seattle at the close of the year, but since that time operations have been suspended.

The marble deposit flanks the eastern side of the granite mass represented on the geologic map, and from its relative position and general character is similar to the Marble Creek deposit farther west. The marble belt is exposed at tide water and forms high bluffs at 200 to 400 feet elevation one-fourth mile back from the shore. In these bluffs it has been prospected by trenches and open cuts. Several diabase dikes crosscut the marble beds. The dikes are faulted and show in many places several feet of displacement, though this faulting as well as the intrusion of the dikes probably occurred previous to the metamorphism of the original limestone beds, as no trace of the fault planes could be seen, and the dikes themselves were much altered and sheared. The marble as exposed in the quarry is not of so good quality as that from the Marble Creek property, being less firm and more coarsely crystalline. Surface cracks and fracture planes are present in the surface exposures, but in the bottom of the pit these features are less pronounced.

MARBLE ISLAND.

Marble Island, a low wooded area of 9 square miles, is one of the larger islands in Davidson Inlet and lies 10 miles due south of Shakan, though by water it is nearly 30 miles distant. On the northwest side of this island marble was first discovered in 1899, and in 1903 a number of claims were located over this portion of the island and a small amount of stripping was done. Samples of this marble were quarried for test purposes and several varieties of good quality obtained. The total developments have not exceeded the assessment requirements.

The marble deposit is exposed in a cove on the northwest side of the island, and at 100 feet elevation, a half mile from the shore, it has been worked by an open cut. A considerable area is underlain by marble, though little is known of its extent or value. Along the eastern shore of the island an area of granitic intrusive rock was noted.

AMERICAN CORAL MARBLE COMPANY.

General description.—The properties of the American Coral Marble Company are located at two localities—(1) at the head of North Arm where twelve claims have been located along the north shore of the Inlet, and (2) at the north entrance to Johnson Inlet, where the company has several claims extending from Dolomi eastward to Clarence Strait (see Pl. I). The principal developments have been made at the North Arm property, and at this point a post-office named Baldwin has been established. Active work at this locality began in 1904 and the marble deposits were prospected during that year. In 1905 a wharf was built, machinery installed, and buildings erected pre-

paratory to quarrying the marble. During 1906, however, practically no work was done, and all of the machinery was removed in 1907. At the Dolomi property a small quarry was started on the hillside, at a point a quarter of a mile northeast of Dolomi postoffice and a few hundred feet from tide water on the Clarence Strait side, and buildings were erected. No operations were in progress at these localities during 1907.

Marble deposits.—The deposits at North Arm and at Dolomi consist of marble beds interstratified with chloritic and calcareous schists, striking northwest with steep dips usually southwest. The surrounding area is mantled by a dense growth of vegetation, and the limits of the deposits have not been definitely determined, though where the marble is exposed it is much fractured, variable in color and composition, and intersected by a few narrow dikes of diabase. The fracture planes were probably formed principally during the period of tilting and folding of the beds and existed before erosion exposed the present surface outcrops. Since that time weathering has accentuated and to some extent increased the number of fracture planes, and it seems probable, however, that in depth these planes, although potentially present as lines of weakness, will become less numerous and will not interfere greatly in quarrying.

Although some parts of the deposits consist of pure white, fine-grained marble of excellent quality, other parts are poorly colored, coarse-grained, and of little commercial value, and it will probably be difficult to obtain large quantities of uniform grade. The better grade is reported to give the following analysis: Calcium carbonate, 94 per cent; alumina, 3.9 per cent; silica, 1.4 per cent; magnesia, 0.7 per cent. Pyrite is also present in small amounts, occurring in thin seams and finely disseminated in some of the marble.

REVILLAGIGEDO ISLAND.

A well-defined limestone belt traverses the eastern portion of Revillagigedo Island in a northwesterly direction and is exposed in Thorne Arm, Carroll Inlet, and George Inlet (see Pl. II). Its widest development is on the north side of George Inlet, near the head, where marble claims known as the Bawden group were located in 1904. The deposit is included in the crystalline schist near the contact with the less-altered slates to the southwest. The marble beds range from 10 to 20 feet in width and are separated by strata of calcareous schist. Their strike is northwest and their dip northeast. The marble is exposed in cliffs near tide water and is of good quality, being relatively free from fracture and joint cracks, finely crystalline, and from white to gray in color. No large developments have been started on this property.

In Carroll Inlet, to the southeast, claims have also been located on the same belt, but at this locality the deposit is not so extensive as in George Inlet.

HAM ISLAND.

Ham Island lies at the junction of Blake Channel and Bradfield Canal, 25 miles southeast of Wrangell (see Pl. III). It is about a mile and a half wide and consists largely of crystalline limestones with interstratified beds of calcareous schist striking N. 35° W. and dipping 75° NE. Intrusive dikes of basalt are common, and across the narrow channel on the mainland and on Wrangell Island wide belts of granite intrude the limestone and schist beds and have probably induced the present crystalline texture in the limestone and thus formed the marble.

Two distinct varieties of marble are found—one fine grained and pure white, the other very coarse grained and pale blue. Several systems of joint planes traverse the deposits, but the joints are widely separated and will not interfere greatly in quarrying. Checks or surface cracks are practically absent, and wide areas of massive marble have been found directly underneath the soil. Much of the marble appears to be free from impurities.

Two groups of claims have been located on this island—the Woodbridge-Lowery group on the west side and the Miller group on the east side. On the former the marble quarried is principally of a white, finely crystalline variety, but at the Miller property the deposit, exposed in a bluff 40 feet high and 100 feet long, is of a coarsely crystalline texture and a bluish color. On both of these properties considerable exploratory work has been done, and large blocks of the marble have been quarried, and from these tombstones and small blocks have been chiseled and polished for local use. The properties are favorably located both for quarrying and transportation.

GRANITE.

DISTRIBUTION.

The granitic intrusive rocks occupy about one-half of the aggregate land area of the Ketchikan and Wrangell districts (see Pl. I). In composition they range from granite to granodiorite or to quartz or hornblende diorite. The core of the Coast Range, as well as the central portion of many of the islands, is composed of this intrusive rock. The metamorphism in the granite, its nonuniformity in color, and the presence of joint cracks, so far as observed, make most of the stone undesirable for building purposes. However, granite masses of good quality, uniform in color, and favorably located for purposes of quarrying, were observed along the mainland up Portland Canal, in

Behm Canal, and at Thomas Bay. On the islands numerous granite stocks occur, portions of which are of massive and uniform texture, though in these stocks are many segregations of the femic minerals, and pyrite is present in many places, rendering the rock less desirable for building purposes.

CHARACTERISTICS.[a]

All the granite masses in this region are similar in composition, having plagioclase feldspar as an essential constituent. Hornblende is the usual dark mineral, though biotite mica is present in much of the rock and in a few places exceeds in amount the hornblende. Quartz is commonly present, though usually in small amounts. The accessory components are apatite, titanite, and magnetite; secondary minerals, due to general metamorphism, are sericite, epidote, zoisite, chlorite, and calcite. Petrographically much of the rock is related more closely to the diorites than to the granites and is usually referred to as a diorite.

The prevailing color is light gray, and in only a few places were pink or reddish masses observed. The grains of the component minerals are ordinarily of medium size, not varying greatly in the different localities. Evidence of the durability of the granite is afforded in many places where long exposure to the influence of weathering has caused little or no disintegration of the surface.

MARKET.

No attempt has yet been made to quarry or even investigate the Alaskan granite. There is practically no market in Alaska for the stone, and along the Pacific coast to the south the demand has been supplied by the quarries in the States of Washington, Oregon, and California.

The long haul necessary to reach the market appears at first unfavorable to granite quarrying along this portion of the northwest coast, but the present freight rate of less than $3 per ton to Puget Sound is not greater than the cost of transportation from some of the quarries in California to the larger cities. The cost of quarrying the stone is estimated at 40 cents per cubic foot, and the proportion of marketable rock obtained from the amount quarried is about 60 per cent.

The value of the production of granite from the States along the west coast amounted to nearly $1,000,000 in 1905. The average selling price per cubic foot for building purposes at the quarries in the coast States in 1906 was as follows: Rough, $0.85; dressed, $2.35; for curbing, $1. For monumental purposes the stone sold for $1 to $2 per cubic foot rough and for $3 to $6 per cubic foot dressed.

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[a] The characteristics of the granitic intrusives are described in detail on pp. 81–89.

The prices do not include the cost of transportation from the quarries to the cities, which is from $0.50 to $3 per ton. This adds from 5 to 30 cents to the cost per cubic foot.

CEMENT.

There are several kinds of cement, the principal kinds being Portland cement and natural cement. Portland cement is produced by burning a finely ground artificial mixture containing essentially lime, silica, and alumina in certain definite proportions. Usually this combination is made by mixing limestone or marl with clay or shale, and in such a mixture should contain about three parts of the carbonate to one part of clayey material. Natural cement is the product of an impure limestone containing from 15 to 40 per cent of silica, alumina and iron oxide. Calcareous and argillaceous rocks suitable for cement making are relatively scarce in the Ketchikan and Wrangell districts. They are metamorphosed, usually containing mica and some pyrite, and are not sufficiently fine grained to be of value. At only one locality—Long Island in Kasaan Bay—have rocks of this sort been located for the manufacture of cement. Here beds of limestone and siliceous shale are exposed around the shores of the island and are apparently of a quality suitable to make cement. The disposition of this product will, however, be confined to the local market as it can not now be profitably shipped to compete with the cement manufactured along the Pacific coast. The reason for this, in the first place, is the high cost of the fuel necessary for its manufacture. The difficulty in obtaining efficient and cheap labor, as compared with the labor of the Puget Sound area and California, must also be considered. The long haul necessary to reach the market is unfavorable to such an industry. To ship the cement rock as mined to a cement factory established somewhere near the point of coal supply and near the market would be the most feasible plan, but this would bring little or no profit, as vast areas of cement rock are exposed near all the larger cities and can supply the cement plants along the coast for many years to come.

MINERAL AND THERMAL SPRINGS.

Cold mineral springs have been found at (1) St. John Harbor on Zarembo Island, (2) at several points near Eddystone Rock, in Behm Canal, and (3) up Unuk River.

At Zarembo Springs the water contains considerable carbon dioxide with various mineral salts, which lend to it an agreeable flavor. The point of outflow, which is covered at high tide, has been incased and a small wharf built over it. The water forces itself up through

a pipe, from which demijohns and barrels are filled and shipped to Seattle, where bottling works have been established.

In Behm Canal the principal spring is situated on the east side of Revillagigedo Island, opposite Eddystone Rock. The waters emerge from fracture cracks in a banded schist complex cut by pegmatite dikes. The flow at this point is greater than at Zarembo Springs. Carbon dioxide and a small percentage of sulphureted hydrogen are present in the water, the latter giving it a disagreeable odor. Small shipments have been made from these springs for the local trade.

On the north bank of Unuk River, about 20 miles from the mouth and 2½ miles below the international boundary, a strongly carbonated spring flows from a fissure in the granite. Its temperature is 7° C. (44° F.) and the daily discharge about 1,000 gallons. With good transportation facilities this spring should prove valuable.

Thermal springs occur at several points in southeastern Alaska and have been found by experience to possess medicinal properties of great value to sufferers from rheumatism and other ills resulting from exposure. The Indians were the first to appreciate the healing power of the springs and made use of them long before the invasion of the white men. Of late years cabins and bath houses have been built at several of the springs for the accommodation of visitors. Southeastern Alaska, however, is not an ideal summer resort, owing to the excessive rain, and the springs can not be so valuable commercially as those in more favored districts.

The springs occur without exception within intrusive granite belts and issue from fracture planes. In temperature they range from 65° C. (150° F.) to 95° C. (203° F.). They are extremely variable in composition, and on cooling precipitate various minerals, forming crust deposits. The rate of discharge is not the same for different springs, and varies, probably, from several hundred to 1,500,000 gallons per day. One of the hottest springs is located near Bailey Bay, Behm Canal, in the Ketchikan district. The water at this point issues from a fissure in the granite in the form of a jet 15 inches high and 1 inch in diameter. On Bell Island, just west of Bailey Bay, and on the north side of Unuk River, 6 miles from its mouth, are similar hot springs, which are frequently visited. The spring with the greatest flow is situated opposite Great Glacier, on Stikine River, above the international boundary, and serves the inhabitants of the Wrangell district. Definite analyses and temperatures of the various waters could not be obtained.

FUTURE OF THE DISTRICTS.

Although a greater or less concentration of copper and gold occurs at various points in the Ketchikan district, there is little to indicate that deposits of much higher grade or greater extent will be found than those at present mined. Large areas still remain unprospected and within these future explorations will probably reveal ore bodies comparable with those now known. The extent of the copper-bearing masses is possibly the most important question to be settled. That outcrops may fail altogether to indicate the value of ground underneath has been shown at several localities, and that the occurrence of the ore is often in limited masses which can be mined out in a short space of time is shown at several mines, though at these localities advanced developments invariably reveal new ore bodies. Under exploitation on the scale being advanced in this district the problem of new ore reserves must inevitably come to the front, and the search for new ore bodies should be vigorously continued by both prospector and mine operator. Such investigations have been satisfactorily extended in the ore-bearing rocks by the use of diamond-drills, which are especially adapted to the search of such scattered ore masses.

Under existing conditions, with the price of copper at 15 cents per pound, it is not possible to mine profitably ore containing less than 60 pounds of copper per ton and the usual gold content of from 75 cents to $1.25 per ton. However, ore containing as low as 40 pounds of copper per ton was mined and shipped at a profit early in 1907, when copper was at a market value of 25 cents a pound. The present mining costs average from $1.50 to $2 per ton, including haulage to the wharf; transportation to the smelters at Tacoma or in British Columbia costs from $1.50 to $2 per ton, depending upon the tonnage shipped; smelting charges are from $3 to $5 per ton, including the losses in treatment. If the ore is smelted in Alaska, transportation is somewhat reduced, though the smelting charges are necessarily increased, as the coke required must be shipped to Alaska and the copper matte or smelter product must be shipped south to Puget Sound.

In some of the copper mines, as on Kasaan Peninsula and near Sulzer, are huge bodies of magnetite containing from 1 to 2 per cent of copper per ton, which can not at present be extracted with profit as a copper ore. It is possible, however, that, with the introduction of a method of concentration by fine grinding and magnetic separation, such an ore may also be mined to advantage, especially if the magnetite can be sold as an iron ore. It is noteworthy that the magnetite is practically free from phosphorus, contains very little sulphur or other impurities, and could be placed on the market as a "Bessemer

ore." The mines and prospects on Kasaan Peninsula alone have revealed a large tonnage of magnetite ore.

Gold ores which are favorably located and in which the greater percentage of the value is free-milling can be profitably mined with a gold content of \$3 to \$10 or more per ton, according to the magnitude of the ore body.

The rapidly increasing output from the copper mines on Prince of Wales Island and the recent discoveries of copper-bearing deposits have brought the Ketchikan district well to the front as a copper-producing area. Little can be said regarding the future of the mines and prospects in the Wrangell district, as their output has been slight. Copper, gold, and silver-lead deposits are being exposed at several localities, some of which give promise of becoming future metal producers.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All of these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except certain maps), on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

GENERAL.

The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper No. 45, 1906, 327 pp.

Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin No. 259, 1905, pp. 18–31.

The mining industry in 1905, by A. H. Brooks. In Bulletin No. 284, 1906, pp. 4–9.

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Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1904: Bulletin No. 259, 1905, pp. 13–17.

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Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin No. 259, 1905, pp. 128–139.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin No. 250, 1905, 64 pp.

Markets for Alaska coal, by G. C. Martin. In Bulletin No. 284, 1906, pp. 18–29.

The Alaska coal fields, by G. C. Martin. In Bulletin No. 314, 1907, pp. 40–46.

Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin No. 263, 1905, 362 pp. (Out of stock; can be purchased from Superintendent of Documents, Washington, D. C., for 35 cents.) Abstract in Bulletin No. 259, 1905, pp. 32–46.

Geographic dictionary of Alaska, by Marcus Baker, second edition by J. C. McCormick. Bulletin No. 299, 1906, 690 pp.

Administrative report, by A. H. Brooks. In Report on progress of investigations of mineral resources of Alaska in 1907. Bulletin No. 345, pp. 5–17.

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Prospecting and mining gold placers in Alaska, by J. P. Hutchins. In Bulletin No. 345, 1908, pp. 54–77.

Water-supply investigations in Alaska in 1906–7, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, 156 pp.

Topographic maps.

Alaska, topographic map of; scale, 1:2500000. Preliminary edition by R. U. Goode. Contained in Professional Paper No. 45. Not published separately.

Map of Alaska showing distribution of mineral resources; scale, 1:5000000; by A. H. Brooks. Contained in Bulletin 345 (in pocket).

Map of Alaska; scale, 1:5000000; by Alfred H. Brooks.

In preparation.

Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Second edition.

SOUTHEASTERN ALASKA.

Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska, by Alfred H. Brooks. Professional Paper No. 1, 1902, 120 pp.
The Porcupine placer district, Alaska, by C. W. Wright. Bulletin No. 236, 1904, 35 pp.
The Treadwell ore deposits, by A. C. Spencer. In Bulletin No. 259, 1905, pp. 69–87.
Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin No. 259, 1905, pp. 47–68.
The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin No. 287, 1906, 161 pp.
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Nonmetallic deposits of southeastern Alaska, by C. W. Wright. In Bulletin No. 284, 1906, pp. 54–60.
The Yakutat Bay region, by R. S. Tarr. In Bulletin No. 284, 1906, pp. 61–64.
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Reconnaissance on the Pacific coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin No. 314, 1907, pp. 82–88.
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Copper deposits on Kasaan Peninsula, Prince of Wales Island, by C. W. Wright and Sidney Paige. In Bulletin No. 345, 1908, pp. 98–115.

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CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS.

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Bering River coal field, by G. C. Martin. In Bulletin No. 259, 1905, pp. 140–150.
Cape Yaktag placers, by G. C. Martin. In Bulletin No. 259, 1905, pp. 88–89.
Notes on the petroleum fields of Alaska, by G. C. Martin. In Bulletin No. 259, 1905, pp. 128–139. Abstract from Bulletin No. 250.
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Notes on copper prospects of Prince William Sound, by F. H. Moffit. In Bulletin No. 345, 1908, pp. 176-178.
Mineral resources of the Kotsina and Chitina valleys, Copper River region, by F. H. Moffit and A. G. Maddren. In Bulletin No. 345, 1908, pp. 127-175.

Topographic maps.

Map of Mount Wrangell; scale, 12 miles = 1 inch. Contained in Professional Paper No. 15. Not issued separately.
Copper and upper Chistochina rivers; scale, 1:250000; by T. G. Gerdine. Contained in Professional Paper No. 41. Not issued separately.
Copper, Nabesna, and Chisana rivers, headwaters of; scale, 1:250000. D. C. Witherspoon. Contained in Professional Paper No. 41. Not issued separately.
Controller Bay region Special map; scale, 1:62500; by E. G. Hamilton. For sale at 35 cents a copy or $21.00 per hundred.
General map of Alaska coast region from Yakutat Bay to Prince William Sound; scale, 1:1200000; compiled by G. C. Martin. Contained in Bulletin No. 335.

In preparation.

The Kotsina-Chitina copper region, by F. H. Moffit.
Chitina quadrangle map; scale, 1:250000; by T. G. Gerdine and D. C. Witherspoon.

COOK INLET AND SUSITNA REGION.

The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits, by G. C. Martin. Bulletin No. 250, 1905, 64 pp.
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Topographic maps.

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Reconnaissance map of Matanuska and Talkeetna region; scale, 1:250000; by T. G. Gerdine and R. H. Sargent. Contained in Bulletin No. 327. Not published separately.
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The Herendeen Bay coal field, by Sidney Paige. In Bulletin No. 284, 1906, pp. 101-108.

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The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin No. 218, 1903, 71 pp.
The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, by L. M. Prindle. Bulletin No. 251, 1905, 89 pp.
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The Yukon-Tanana region, Alaska; description of the Circle quadrangle, by L. M. Prindle. Bulletin No. 295, 1906, 27 pp.
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The Circle Precinct, Alaska, by Alfred H. Brooks. In Bulletin No. 314, 1907, pp. 187–204.
The Yukon-Tanana region, Alaska; description of the Fairbanks and Rampart quadrangles, by L. M. Prindle, F. L. Hess, and C. C. Covert. Bulletin No. 337, 1908, 102 pp.
Occurrence of gold in the Yukon-Tanana region, by L. M. Prindle. In Bulletin No. 345, 1908, pp. 179–186.
The Fortymile gold placer district, by L. M. Prindle. In Bulletin No. 345, 1908, pp. 187–197.
Water supply of the Fairbanks district in 1907, by C. C. Covert. In Bulletin No. 345, 1908, pp. 198–205.

Topographic maps.

Fortymile quadrangle; scale, 1:250000; by E. C. Barnard. For sale at 5 cents a copy or $3 per hundred.
Yukon-Tanana region, reconnaissance map of; scale, 1:625000; by T. G. Gerdine. Contained in Bulletin No. 251, 1905. Not published separately.
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Circle quadrangle, Yukon-Tanana region; scale, 1:250000; by D. C. Witherspoon. Contained in Bulletin No. 295. Not issued separately.

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Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, 156 pp.
Fairbanks quadrangle map; scale, 1:250000; by D. C. Witherspoon. Contained in Bulletin No. 337, 1908.
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Fairbanks Special map; scale, 1:62500; by T. G. Gerdine and R. H. Sargent.

SEWARD PENINSULA.

A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900, by A. H. Brooks, G. B. Richardson, and A. J. Collier. In a special publication entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," 1901, 180 pp.
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A reconnaissance of the northwestern portion of Seward Peninsula, Alaska, by A. J. Collier. Professional Paper No. 2, 1902, 70 pp.
The tin deposits of the York region, Alaska, by A. J. Collier. Bulletin No. 229, 1904, 61 pp.
Recent developments of Alaskan tin deposits, by A. J. Collier. In Bulletin No. 259, 1905, pp. 120–127.
The Fairhaven gold placers of Seward Peninsula, by F. H. Moffit. Bulletin No. 247, 1905, 85 pp.
The York tin region, by F. L. Hess. In Bulletin No. 284, 1906, pp. 145–157.
Gold mining on Seward Peninsula, by F. H. Moffit. In Bulletin No. 284, 1906, pp. 132–141.
The Kougarok region, by A. H. Brooks. In Bulletin No. 314, 1907, pp. 164–181.

Water supply of Nome region, Seward Peninsula, Alaska, 1906, by J. C. Hoyt and F. F. Henshaw. Water-Supply Paper No. 196, 1907, 52 pp. (Out of stock; can be purchased of Superintendent of Documents for 15 cents.)
Water supply of the Nome region, Seward Peninsula, 1906, by J. C. Hoyt and F. F. Henshaw. In Bulletin No. 314, 1907, pp. 182-186.
The Nome region, by F. H. Moffit. In Bulletin No. 314, 1907, pp. 126-145.
Gold fields of the Solomon and Niukluk river basins, by P. S. Smith. In Bulletin No. 314, 1907, pp. 146-156.
Geology and mineral resources of Iron Creek, by P. S. Smith. In Bulletin No. 314, 1907, pp. 157-163.
The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin No. 328, 1908, 343 pp.
Investigation of the mineral deposits of Seward Peninsula, by P. S. Smith. In Bulletin No. 345, 1908, pp. 206-250.
The Seward Peninsula tin deposits, by Adolph Knopf. In Bulletin No. 345, 1908, pp. 251-267.
Mineral deposits of the Lost River and Brooks Mountain regions, Seward Peninsula, by Adolph Knopf. In Bulletin No. 345, 1908, pp. 268-271.
Water supply of the Nome and Kougarok regions, Seward Peninsula, in 1906-7, by F. F. Henshaw. In Bulletin No. 345, 1908, pp. 272-285.

Topographic maps.

The following maps are for sale at *5 cents a copy*, or $3 per hundred:
Casadepaga Quadrangle, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Grand Central Special, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Nome Special, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.
Solomon Quadrangle, Seward Peninsula; scale, 1:62500; by T. G. Gerdine.

The following maps are for sale at *25 cents a copy*, or $15 per hundred:
Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.
Seward Peninsula, northwestern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.
Seward Peninsula, southern portion of, topographic reconnaissance of; scale, 1:250000; by T. G. Gerdine.

In preparation.

Water-supply investigations in Alaska, 1906 and 1907, by F. F. Henshaw and C. C. Covert. Water-Supply Paper No. 218, 1908, 156 pp.
Geology of the area represented on the Nome and Grand Central Special maps, by F. H. Moffit, F. L. Hess, and P. S. Smith.
Geology of the area represented on the Solomon and Casadepaga Special maps, by P. S. Smith.
The Seward Peninsula tin deposits, by A. Knopf.

NORTHERN ALASKA.

A reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers, by W. C. Mendenhall. Professional Paper No. 10, 1902, 68 pp.
A reconnaissance in northern Alaska across the Rocky Mountains, along the Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901, by F. C. Schrader and W. J. Peters. Professional Paper No. 20, 1904, 139 pp. (Out of stock; can be purchased of Superintendent of Documents for 40 cents.)
Coal fields of the Cape Lisburne region, by A. J. Collier. In Bulletin No. 259, 1905, pp. 172-185.
Geology and coal resources of Cape Lisburne region, Alaska, by A. J. Collier. Bulletin No. 278, 1906, 54 pp.

Topographic maps.

Fort Yukon to Kotzebue Sound reconnaissance map of; scale, 1:1200000; by D. L. Reaburn. Contained in Professional Paper No. 10. Not published separately.
Koyukuk River to mouth of Colville River, including John River; scale, 1:1200000; by W. J. Peters. Contained in Professional Paper No. 20. (Out of stock.) Not published separately.

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J C Branner

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 348

COAL RESOURCES

OF THE

RUSSELL FORK BASIN

IN KENTUCKY AND VIRGINIA

BY

RALPH W. STONE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

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ILLUSTRATIONS.

AL RESOURCES OF THE RUSSELL FORK BASIN IN KENTUCKY AND VIRGINIA.

By Ralph W. Stone.

PART I.—THE ELKHORN COAL DISTRICT, KENTUCKY.

INTRODUCTION.

?easons for this survey.—For many years it has been known that uminous coal of good quality occurs in abundance in Pike and tcher counties, Ky. The region north of Pound Gap on the ıdwaters of Elkhorn and Shelby creeks and of Boone Fork of ntucky River has been particularly noted as a possible source of arge amount of fuel. This region has enjoyed a good reputation ong investors for the amount and quality of the coal present, the ly question as to its immediate value being based on the lack of nsportation facilities. A large market is readily accessible from mouth of Big Sandy River, the natural entrance to the region.

For several years the United States Geological Survey has had der advisement an investigation of the geology and mineral re- ırces of the region as soon as adequate topographic maps on which base the work should be prepared. As new topographic maps re not immediately forthcoming and as a railroad has recently ən built which will probably lead to the early development of the ld, it was decided to make a reconnaissance survey of the drainage sin of Russell Fork of Big Sandy River in the summer of 1906. e area of this basin, which is largely in Virginia, is approximately square miles, and, as the writer was working alone during greater part of the thirteen weeks given to the task, it was not sible to study details of structure and stratigraphy. It was not ɪnded that this should be the final survey of the region, but ıer that the whole area should be visited and as much informa- ı obtained concerning the number, extent, and character of the l beds as was possible in the limited time available. The first t of this report deals with the Kentucky portion of the basin of ssell Fork, describes the coal found there, and gives a brief ac- ınt of the structure and stratigraphy.

Previous investigation.—In 1887 the Kentucky Geological Survey published preliminary reports on the southeastern Kentucky coal fields, by A. R. Crandall and G. M. Hodge, and in 1900 the report of the inspector of mines of Kentucky contained the results of investigations made by Prof. C. Newton Brown, who was detailed by the War Department to investigate the mineral wealth of Big Sandy Valley at the time there was a movement to provide for slack-water navigation on the river. Professor Brown's report was the prinicipal source of information concerning the coal of the region until the Kentucky Geological Survey, in October, 1906, issued, as its Bulletin No. 4, a report by A. R. Crandall, entitled "The Coals of Big Sandy Valley." Ten pages of this report deal with the region here described.

Individuals and companies have made thorough investigations of practically the entire district. The Big Sandy Company and the Northern Coal and Coke Company have made areal and geologic surveys of their extensive holdings, but their reports are private. The Big Sandy Company has a lithograph map of the Elkhorn field lying south of Russell Fork which shows the outcrops of the principal coal beds, the geologic structure, and the location of several hundred prospects. This map was made by E. V. d'Invilliers, of Philadelphia. A copy furnished to the writer by the company, together with a tracing of that portion of the original map representing the country north of Russell Fork, formed the base for the field notes and for a large part of the map which accompanies this report (Pl. I). Private reports by R. N. Dickman, E. V. d'Invilliers, A. M. Miller, Neil Robinson, Joseph Sillyman, and others were seen by the writer.

Method of work.—The field work on which this report is based was done between July 24 and September 10, 1906. G. H. Ashley, geologist in charge of Appalachian coal surveys, spent the first week of the season with the party. C. W. Dodge, jr., assisted the writer after August 24.

The work consisted largely in making road sections to determine the structure, in measuring cliff sections to get the stratigraphic succession, and in measuring coal beds wherever exposures could be found. In a region so heavily timbered as this there are but few natural exposures of the coal beds, and the number of coal sections measured would have been small but for the extensive prospecting done by the companies that have been investing in coal lands. As more than a year had passed since most of the trenches were dug, many of them were filled and the coal made inaccessible except by the expenditure of considerable time and labor. It was not practicable in the present survey to reexcavate, and therefore measurements were necessarily confined to those prospects which were open

and could be located, to the banks which are worked for family use each winter, and to the natural outcrops. One hundred and fifty measurements of coal beds were thus obtained, sufficient to prove the character and extent of the coal throughout the field. All coal sections given in this report, except two of the Flatwoods bed, were measured by the writer or his assistant, Mr. Dodge. The locations of prospects shown on the map of the Big Sandy Company were of great assistance in finding places where sections of coal beds might be measured. Stadia elevations given on the map were accepted as true altitudes, and aneroids were constantly referred to them.

Acknowledgments.—The writer is indebted to the officers of the Big Sandy Company, to the officers of the Northern Coal and Coke Company, and particularly to W. T. Griffith, civil engineer, of Pikeville, Ky., J. C. C. Mayo, of Paintsville, Ky., and James W. Fox, of New York, for maps, information, and photographs. C. W. Dodge, jr., gave efficient assistance in the field, and in the office has prepared the map and the figures which accompany the report. G. H. Ashley, geologist in charge of Appalachian coal surveys, has exercised oversight of the work and offered many valuable suggestions. David White has contributed a section on the correlation of the Elkhorn coals. The residents of the district extended kindness to the writer everywhere he went, and he wishes to state that in every locality, without exception, he found unfailing courtesy and hospitality shown to the stranger.

GEOGRAPHY AND HISTORY.

GEOGRAPHIC POSITION.

The Elkhorn coal field is situated close to the eastern boundary of Kentucky, about midway between Huntington, W. Va., and Bristol, Va. The field lies 75 miles south of Ohio River, in the drainage basin of Russell Fork of Big Sandy River. It is a part of the eastern Kentucky coal field, which extends over several counties and is divided by natural boundaries into smaller districts, of which the Elkhorn coal field is one. The Elkhorn field as here discussed and described is a triangular area having its greatest length along Pine Mountain and the State line. The distance from the head of Grassy Creek to the head of Elkhorn Creek is 25 miles. The greatest width of the field is about 10 miles, which is the distance in a straight line from the northern end of Pine Mountain at the Breaks to the mouth of Russell Fork at Millard. This area is all in Pike County except the extreme head of Elkhorn Creek, which is in Letcher County.

Russell Fork divides the field into two unequal parts. The northern part, from the river to the divide between it and Levisa Fork, contains about 30 square miles and is drained largely by Powell, Ferrell,

Beaver, and Grassy creeks, all of which are from 3 to 4 miles in length. The southern part is much larger, having about 100 square miles, and includes Elkhorn, Pond, and Marrowbone creeks. Elkhorn Creek rises on the north side of Pound Gap and flows northeast 20 miles parallel with Pine Mountain to join Russell Fork at Praise (Elkhorn City). Marrowbone Creek, which is 8 miles long, heads at Ashcamp Gap and empties into Russell Fork at Regina, 8 miles below the mouth of Elkhorn Creek. Pond Creek lies between the two and is scarcely 4 miles long.

TOPOGRAPHY.

The topography of the eastern part of Pike County is rugged, almost mountainous. The elevation of the main streams is between 700 and 900 feet above sea level, while the summits of the ridges are over 1,500 feet above tide. In the Flatwoods area, which exceeds 2,500 feet in general elevation, there is a suggestion of the old Cumberland plateau, of which eastern Kentucky forms a deeply dissected part. This broad, level mountain top corresponds closely with the old plateau, which has an elevation of approximately 2,400 feet at Cumberland Gap and, rising northward, is recognized at 3,500 feet on New River. The Cumberland plateau is the oldest, highest, and easternmost of the Allegheny plateaus, and is so deeply eroded in this region that but little trace, the merest suggestion of it, remains. Its general slope was westward.

The valleys have narrow floors and steep walls that rise abruptly several hundred feet to the narrow ridge tops. Because there is practically no level upland surface and the ridges are difficult of access, settlement was first made on the banks of the main stream, whence it spread gradually up the side ravines.

The elevation of Russell Fork at Millard is 680 feet above tide, at the mouth of Road Creek 720 feet, at the mouth of Ferrell Creek 755 feet, and at the State line in the Breaks about 900 feet. This difference of 220 feet in 14½ miles gives an average fall of a little over 15 feet per mile. Elkhorn Creek falls 760 feet from head to mouth, an average of 38 feet per mile for 20 miles. Marrowbone Creek has a fall of nearly 50 feet per mile in the lower 6 miles of its course.

Pine Mountain, which marks the southern boundary of the Elkhorn field, presents a type of topography found in the Appalachian Valley from New York to Alabama. It is a ridge formed by the upturning of hard strata, the Lee conglomerate, which dips southeast at an angle of 25° and which is bounded on the northwest by a great fault. The crest of Pine Mountain is comparatively straight, but more or less serrate. It has a general altitude of 3,000 feet, with no low gaps between Pineville and the Breaks of Sandy, a distance of

85 miles. The heavy sandstone and conglomerate beds resist erosion, so that the crest has retreated but little from the line of the fault. This fault brings the coal-bearing rocks on the west to an abrupt end on the flank of the mountain and raises lower barren rocks high above them on the east, making a scarp which is difficult to cross.

Because of the deeply dissected character of the region, its narrow valleys and sharp-crested ridges, and because the base of the coal-bearing formation is at or not far below water level, the workable coals, which are in the middle of the formation, occur high in the hills. Within 2 miles of Russell Fork, on both sides, the Elkhorn coals are so high in the hills that they have only a small body and very irregular outlines.

This topography, however, does not hinder coal-mining operations, for by frequent bridging or fording of the stream room may be found on each valley floor for the accommodation of a highway and railroad. Of necessity any considerable settlement must be extended along the valleys.

ACCESSIBILITY OF THE REGION.

Pine Mountain, which forms the State line and cuts off the coal field on the east, has always hindered approach from Virginia. To the east it presents a steep, timbered slope rising 1,500 to 2,000 feet above the surrounding country to a crest in which there are no pronounced gaps for many miles. The Breaks of Sandy, at the northern end of the mountain, through which the drainage of Dickenson County, Va., finds its way westward, is a box canyon a thousand feet deep and a difficult place in which to build either highway or railroad. Its precipitous rocky walls, capped with "chimneys" and towers, with the dashing stream far below, make some of the wildest scenery to be found in this section of the country.

On account of this great natural barrier on the southeast practically all approach to the region is from the north, by way of Big Sandy River. Until 1906 Pike County was accessible only by wagon, except at intervals when a flood stage on the river made it possible for steamers of shallow draft to ascend as far as Pikeville, but this method of transportation was infrequent and precarious.

Highways over which wagons may pass without difficulty are confined to the valleys of the main streams. In many places the valley floor is so narrow that the road and stream bed are coincident or cross each other at intervals. The principal road to this coal field is the highway from Pikeville to Virginia via the Breaks of Sandy. In the region shown on Pl. I it extends up the left side of Russell Fork to the mouth of Grassy Creek, which it ascends to reach the upland and pass around the Breaks. Another much-traveled road runs up Marrowbone Creek, over Ashcamp Gap, to the mouth of

Ashcamp Creek, where it joins the road that extends along Elkhorn Creek. Wagons cross Pine Mountain over Pound Gap at the head of Elkhorn Creek and over Blowing Rock Gap opposite Ashcamp Creek. There is a haul or sled road over the mountain at Osborn Gap, opposite Shelby Gap, which is halfway between the gaps just mentioned and about 15 miles from the mouth of Elkhorn Creek. There are also roads up Beaver, Ferrell, and Road creeks, crossing the divide to Levisa Fork.

There are no roads on the ridges. Numerous bridle paths make practically all parts of the region accessible to travelers on horseback.

In July, 1906, the Big Sandy branch of the Chesapeake and Ohio Railway was completed from Pikeville to Elkhorn City (Praise post-office), at the mouth of Elkhorn Creek, and to Hellier, near the head of Marrowbone Creek. This railroad makes part of the Elkhorn coal field readily accessible, and affords opportunity for the development of the extensive fuel resources which had not been touched because transportation facilities were lacking. With the coming of the railroad interest in the field has increased and several mines are being opened.

Propositions to tap the field by railroads from the east or south have been frequently promulgated. In 1906 surveyors were working in Dickenson County on the proposed line of the South and Western Railway, which aims at tunneling Sandy Ridge at Trammel Gap, crossing Dickenson County by way of McClure Creek or Cranes Nest River, following down Russell Fork to the Breaks at the north end of Pine Mountain, and connecting at Elkhorn City with the Chesapeake and Ohio Railway. Another proposed route extends up Kentucky River to the head of Boone Fork, down Elkhorn Creek to Shelby Gap, and thence down Shelby Creek. Some grading was done at the head of Shelby Creek and in Shelby Gap to hold the location. In the Breaks of Sandy considerable excavating and grading has been completed, but in the summer of 1906 construction work was not being done on any of the proposed lines.

FOREST.

Originally this entire region was covered with a mantle of hardwood forest. The valley floors and the lower portions of the steep mountain slopes are cleared, but the upper slopes and tops of the ridges are as yet heavily covered with timber. Logging has been carried on in the valley for fifty years, the logs being rafted or floated singly down the river at high water to mills on the Ohio. Logs that have been cut and rolled into the river are strewn along the banks and bars waiting for a "mountain tide." Rafts are sent

A. LOG RAFTS ON BIG SANDY RIVER.

Showing river at flood and source of mine timber.

B. CLIFFS OF LEE CONGLOMERATE IN THE BREAKS OF BIG SANDY, NORTH END OF PINE MOUNTAIN.

Photos loaned by Jno. C. C. Mayo.

ut with every big stage of the river, but many logs still remain randed. In the Breaks of Sandy a jam, estimated at 40,000 logs, hich failed to come down for four years because the river did not se enough, went out on a flood in January, 1907.

The most valuable wood native to the region, the black walnut *Juglans nigra*), is very rare now in trees of any considerable size. n the early days walnut logs were split for rails and firewood, and venty-five years ago the Singer Sewing Machine Company bought rge numbers of walnut trees at 25 cents a piece. Now a black-alnut stump will bring $25 or more.

Chestnut (*Castanea dentata*) and yellow poplar (*Liriodendron lipifera*) are not so common as formerly. At present white and d oak (*Quercus alba* and *Q. rubra*) are being culled rapidly and ade into staves, which are shipped by the railroad. Among the ore common trees found in the Elkhorn region and in eastern entucky in general are the sugar maple (*Acer saccharum*), white ash *Fraxinus americana*), beech (*Fagus americana*), hickory (*Hicoria lba*), basswood (*Tilia americana*), and sycamore (*Platanus occi-entalis*). Less common, but still not infrequent, are the buckeye *Æsculus octandra*), papaw (*Asimina triloba*), and cucumber tree *Magnolia acuminata*).

To-day the landscape from any of the highest summits presents a iew of low mountains completely clad with timber and with only few inconspicuous patches cleared for corn. The lumberman, how-er, is beginning to make rapid inroads, and the day is not far dis-nt when most of the mountains will be stripped of their cover. here is timber in these mountains of quality and in abundance suffi-ent to meet the demands of extensive coal-mining operations and warrant the establishment of furniture, spoke, handle, and wagon tories. With the stripping of the forest, however, the soil on the ep hills will be rapidly washed away and the slopes left bare and rile. Worst of all, with the removal of the forest will come devas-ing floods that will do incalculable damage to the lands and indus-es on the banks of Russell Fork. Pl. II, *A*, shows Big Sandy ver at flood stage and several rafts of logs, indicating the source an abundance of timber for mine supports and for outside con-uction.

EARLY DEVELOPMENT OF MINERAL RESOURCES.

It is probable that small coal banks were opened as early as the il war, but they must have been few and little more than "gopher les." One of the oldest known banks, said to have been opened er thirty years ago, is on Harless Creek, 1½ miles above its mouth, n the land of Butler Ratliff. This bank originally supplied fuel or the locomotive of a small steam tramroad which was built up the

creek for logging. The need of fuel for blacksmithing also was an early incentive for digging coal. Some few banks have been open and supplying winter fuel to one or two families for a dozen or fifteen years, but most of the prospecting to locate the coal beds has been done since 1902. Much of it has consisted of simple trenching to face up the coal and measure it, after which the opening has caved. In a few places after the facing up some one has taken the opportunity to drift in and timber the opening so as to keep the coal accessible. The amount of development in this field prior to 1903 was extremely meager and of little or no importance. Even to this day, in spite of the abundance of coal, the principal fuel used in this district is wood.

PRESENT DEVELOPMENT AND PRODUCTION.

Except the few small banks which are kept open for family use and one or two which supply a small custom trade, the development of the field is confined to the upper portion of Marrowbone Creek, where five mines have been opened. The buying of mineral rights was begun by R. M. Broas about July, 1885, and by Wilder and Stratton in 1888. Their purchases were taken over by the Elkhorn Coal and Coke Company about 1893. By the efforts of R. A. Hellier, this company procured a considerable block of coal land and transferred its rights to the Big Sandy Company in 1902.

The Big Sandy Company now owns a large proportion of the mineral rights of the area represented on the accompanying map. John C. C. Mayo commenced buying coal rights in this field in 1892 and continued until he organized the Northern Coal and Coke Company in 1901. Practically all of the coal land between Shelby Gap and the head of Elkhorn Creek is owned by this company, which has made a number of openings to show the character and value of the coal and has built beehive ovens near the head of Elkhorn Creek to test the coking quality of the Upper Elkhorn coal. The Northern Coal and Coke Company exhibited at the Louisiana Purchase Exposition, at St. Louis, specimens of coke made at these ovens, and also a complete section of the 8-foot coal bed. Active development of this company's property is delayed by lack of railroad facilities. The Virginia Iron, Coal and Coke Company owns about 2,000 acres of coal land on Pond Creek, but there is no development of the property other than the opening of a few small banks.

None of this property was of immediate value so long as there was no means of transportation. The construction of the Big Sandy branch of the Chesapeake and Ohio Railway to the mouth of Elkhorn Creek and up Marrowbone Creek to Cassell Fork was completed in June, 1906. Before the completion of the railroad the Big Sandy Company had leased coal-mining rights to five newly formed companies, and preparations for extensive mining were begun at once in a

many different localities on Marrowbone Creek. The companies which began active development work in the spring of 1906 are the Greenough Coal and Coke Company, the Edgewater Coal and Coke Company, the Henry Clay Coal and Coke Company, the Marrowbone Coal and Coke Company, and the Pike Coal and Coke Company.

Outside construction and drifting began in February, and in June the Pike Coal and Coke Company shipped the first car of coal. In July, soon after the completion of the railroad, the Pike and Greenough mines began shipping regularly, the former loading cars from a temporary chute and the latter from a permanent tipple. The Greenough Company is mining the Upper Elkhorn bed, and the Pike Company the Lower Elkhorn. In October, 1906, the Henry Clay Company began loading Lower Elkhorn coal from its permanent tipple. At that date the railroad grade was not completed to the Edgewater mine, which is at the head of Marrowbone Creek, and the tipple for the Marowbone mine was not built. A description of the stage of development of the property of these five companies in October, 1906, will show the prospects of the field.

The Edgewater Coal and Coke Company is developing a lease at the head of Marrowbone Creek one-half mile north of Ashcamp Gap. Main gangways are being driven on both the Upper and Lower Elkhorn beds. In October the gangway on the upper bed was in 140 feet with a course S. 85° E., and on the lower bed 370 feet on a course S. 83° E., with a parallel air course not so long. A tipple and incline were being built. The Edgewater mine is seven-eighths mile from the railroad. A grade for a railroad spur was built to it in the spring of 1906, but was too steep and a longer one with easier grade was built in the fall. Outside construction, including miners' houses, was barely begun.

The Greenough Coal and Coke Company has driven 600-foot gangways on the upper and lower beds, one above the other, at a point about 300 yards above the mouth of Cassell Fork. The upper mine has two right and two left entries started. It is reported that the coal nearly pinched out in the face of the lower mine, but this was not confirmed as the heading was inaccessible on account of water. Coal was being shipped from the upper bed. Miners' houses were built, and the tipple and gravity incline at this mine were the first ones completed on the creek. A roadway has been graded up the mountain side to the upper mine, which is about 350 feet above the stream.

The Henry Clay Coal and Coke Company has a lease on a block of coal which lies on the north side of Marrowbone Creek between Poorbottom Creek and Big Branch. Development was begun by building a group of houses and other necessary buildings along the railroad and by starting a mine on the Lower Elkhorn bed. In October, 1906,

the entry was 550 feet long and was provided with a parallel air course. The course of the main entry is N. 75° W., for 450 feet, where it turns N. 45° W. Cars from this entry are hauled around the face of the hill about 100 yards to the tipple incline, which is located on the point of a spur. An opening had been driven about 70 feet on the upper bed on the opposite side of the spur and was progressing rapidly in a N. 45° W. direction. This mine began shipping coal from the lower bed in October. The tipple is directly on the railroad, so that only a siding is necessary.

The Marrowbone Coal and Coke Company undertook the development of their property in May, 1906, and in October had not completed the tipple and siding, although the building of this part of the plant and of houses for the miners was progressing. This company's lease is on the south side of Marrowbone, nearly opposite the mouth of Rockhouse Creek. At this point the Upper Elkhorn coal is about 570 feet above the railroad and stream. Entries on both beds are driven S. 30° E. One on the upper bed had reached 127 feet and two on the lower bed 125 feet.

The Pike Coal and Coke Company began construction of houses and a company store in February and shipped coal early in July, 1906. More work was done on the lower than on the upper bed, and on September 1 the lower mine had a main gangway 720 feet long with a parallel air course, and a left entry 350 feet long, with an air course. Three rooms from 30 to 70 feet long have been cut from this entry. At the same time the entry of the upper mine had advanced 246 feet. Foundation for a permanent tipple was laid in October, cars then being loaded from a temporary chute.

All of these mines are using the room-and-pillar system, and the coal is shot from the solid. Mining machines have not yet been installed. The mines are ventilated by furnace, and the hauling is done by mules. Natural drainage is obtained. Miners are paid $3.75 a yard for driving headings 6 feet high and for mining at the rate of 60 cents for a 1½-ton car. Miners working in the Lower Elkhorn bed are paid 70 cents a car, the higher rate being demanded for throwing out the laminated coal. All of the mines have had difficulty in getting enough miners and were working short-handed. The daily production of the three mines which were shipping in October, 1906, was as follows:

Daily production of mines on Marrowbone Creek, October, 1906.

	Tons.
Greenough mine from Upper Elkhorn bed	60
Henry Clay mine from Lower Elkhorn bed	50
Pike mine from Lower Elkhorn bed	90

A very rapid increase in the amount of coal produced and shipped was possible as soon as outside construction could be completed and a greater number of miners procured.[a]

From the above statements it is apparent that here is a coal field as yet practically untouched which is just entering upon a period of active development. Whether the mines above described are located in the best part of the field so far as thickness and quality of the coal are concerned is a question. Certainly there are areas in which the beds are thicker, or at least one bed has a much greater thickness than either of those mined on Marrowbone Creek, but in one place the body of coal to work upon is small and the cover is slight, being located near the top of narrow-crested ridges, and in another place the desirable district is much less accessible. It is possible that from the beginning here described a considerable mining industry may grow up and the Elkhorn field of Kentucky become known for the excellent quality of its steaming and coking coal.

MARKET.

The natural outlet for the coal and coke of the eastern Kentucky fields is the Ohio Valley. Geographic conditions make the market of the immediate future lie to the north, west, and south. The Appalachian Mountains form a natural barrier which hinders the delivery of coal to the east. There is a possibility, however, that within a few years there may be a railroad from the Atlantic seaboard directly across the mountains to this coal field. The market in the Ohio and Mississippi valleys is of sufficient size to handle all of the coal that will be poured into it. With Chicago receiving 10,000,000 tons of bituminous coal annually, Cleveland 6,000,000, Cincinnati 4,000,000, and Toledo and St. Louis 7,000,000 each, there is an abundant market to which the Elkhorn field is directly accessible.

The Chesapeake and Ohio Railway, as explained in the introduction, extends into the heart of this field. It needs but the construction of a few miles of track to bring any point in the field in direct connection with the main line. Millard, at the mouth of Russell and Levisa forks, is a natural collecting point. The following table shows the distances and routes from Millard, in the heart of the Elkhorn field, to some of the principal markets which the field may supply:

Distances and routes from Millard.

	Miles.
Ashland and Ironton, via Chesapeake and Ohio Railway	121
Cincinnati, via Chesapeake and Ohio Railway	267
Columbus, via Chesapeake and Ohio Railway and Norfolk and Western Railway	255

[a] In April, 1907, the daily capacity of the five mines was about 1,000 tons, but the supply of cars was short and irregular.

	Miles.
Cleveland, via Chesapeake and Ohio Railway, Norfolk and Western Railway, Cleveland, Cincinnati, Chicago and St. Louis Railway	390
Toledo, via Chesapeake and Ohio Railway, Norfolk and Western Railway, and Hocking Valley Railway	370
Chicago, via Chesapeake and Ohio Railway and Cleveland, Cincinnati, Chicago and St. Louis Railway	573
Indianapolis, via Chesapeake and Ohio Railway and Cleveland, Cincinnati, Chicago and St. Louis Railway	377
Lexington, via Chesapeake and Ohio Railway	245
Louisville, via Chesapeake and Ohio Railway	330
St. Louis, via Chesapeake and Ohio Railway and Southern Railway	604
Nashville, via Chesapeake and Ohio Railway and Louisville and Nashville Railroad	517

The relation of the Elkhorn field to these markets is illustrated in the accompanying sketch map (fig. 1).

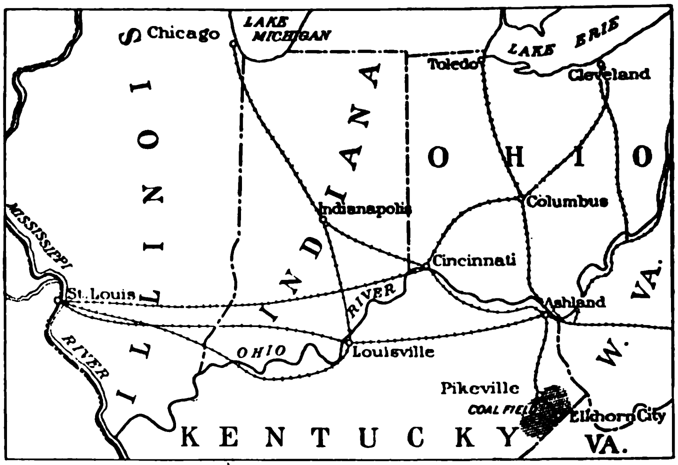


FIG. 1. Sketch map showing location of Elkhorn coal field with relation to markets.

GENERAL GEOLOGY.

STRATIGRAPHY.

GENERAL DESCRIPTION.

The rocks exposed at the surface in the Elkhorn coal field belong to the lower part of the Carboniferous system. They consist, beginning with the lowest, of the Newman limestone, Pennington shale, Lee conglomerate, and a coal-bearing series which has not been divided into formations. It is possible that the Chattanooga shale, which lies next below the Newman limestone, is above water level on the north side of Pine Mountain, near the head of Elkhorn Creek, but if it is raised above the overturned edges of the coal-bearing rocks in this field it is likely that talus from the fault scarp conceals it.

NEWMAN LIMESTONE.

This formation, which includes all the strongly calcareous rocks n this part of the geologic column, is named from Newman ridge, n northern Tennessee. It varies in thickness from 200 or 300 feet ıp to 2,600 feet. The formation is not all limestone, but includes :alcareous and sandy shales and sandstones. Massive and pure imestone forms at least the lower half and there are some chert ıodules at the base. The Newman limestone is well exposed at Big Stone Gap, Wise County, Va., where it has a thickness of 829 feet.[a] The lower 400 feet is solid limestone, and the upper part is com-)osed of dark shales and sandstones with thin beds of impure limestone.

In the Elkhorn field exposures of the Newman limestone are nunerous in sheer cliffs on the north side of Pine Mountain, but neither he thickness, limits, nor section of the formation could be obtained vith any degree of accuracy on any of the roads that cross the nountain. It is best shown on the Blowing Rock Gap road. Here imestone is found through a vertical distance of 650 feet, the high- :st outcrop seen in the road being about 400 feet below the gap. No :ocks in place were seen within 100 feet above the highest or below the owest limestone outcrop, so that considering the dip of the beds, here is ample room for 1,000 feet of this formation. Shaly sandtones and red shale are contained in the upper part of the forma- .ion as seen on this road. The limestone itself is blue to drab or ight gray, and weathers white, so that the outcrops and bowlders of t are conspicuous.

On the road ascending the mountain from Shelby Gap to Osborn Gap almost no limestone is exposed. In a vertical distance of 800 'eet between beds of sandstone only one outcrop of limestone was ıoted. On Pound Gap road about 100 feet of limestone is overlain by a heavy sandstone supposed to be the bottom member of the Pen- ıington and is underlain by 15 feet of shale, below which is sandstone. Whether these rocks belong in the Newman is not certain, but it seems probable that they do. The lowest outcrop of limestone is about !50 feet above the supposed line of the fault. The writer is of the opinion that only 350 feet of this formation, including sandstone, hale, and 100 feet of limestone, is exposed here, and that the lower part of the formation, made up of heavy beds of limestone, was ever raised to the surface.

PENNINGTON SHALE.

Above the Newman limestone lies a series of variegated shales and ındstones of variable thickness. Green, blue, olive, red, and purple

[a] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: ull. U. S. Geol. Survey No. 111, 1893, p. 38.

shales are the distinctive features of the formation. On the south slope of Powell Mountain it has an extreme thickness of 1,300 feet. At Pennington Gap, the type locality, and at Big Stone Gap it is 1,025 feet thick; at Hurricane Gap, in Pine Mountain, it is 890 feet thick. At Big Stone Gap there is over 250 feet of fairly heavy sandstone at the bottom of the formation.[a]

On the north side of Pine Mountain at Blowing Rock Gap there is a concealed interval of about 100 feet above the highest outcrop of limestone. Above this there is about 300 feet of sandstone (principally), supposed to be the lower portion of the Pennington. Overlying a very heavy sandstone which makes a strong cliff just below the gap is a mass of strongly colored shale which is exposed in the gap itself. The Lee conglomerate lies only a few feet above. There is then at least 500 or 600 feet of Pennington. Either the variegated shales and thin sandstones which appear farther south to the thickness of several hundred feet were not laid down here or a considerable portion of them was worn away as a land area previous to the deposition of the Lee conglomerate.

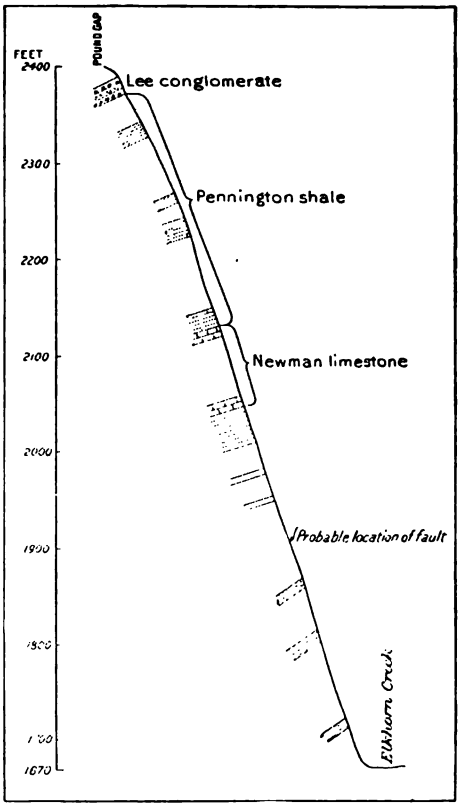


FIG. 2.—Section on road from Pound Gap to Elkhorn Creek.

At Pound Gap from the base of the Lee conglomerate to the base of a heavy sandstone resting on white limestone, which is believed to be the top of the Newman, there is a vertical interval of 250 feet, but the thickness of the Pennington is considerably greater. The dip of the rocks ranges from 18° to 25°, but the actual thickness of the formation was not determined because the horizontal factor was unknown. Typical red and green Pennington shales are exposed in the midst of the interval. The accompanying section (fig. 2) from the north side of the mountain is out of pro-

[a] Campbell, M. R., Geology of the Big Stone Gap coal field of Virginia and Kentucky: Bull. U. S. Geol. Survey No. 111, 1893, p. 37.

portion, the horizontal distance from Elkhorn Creek to the crest of the mountain being approximately three-fourths of a mile.

The thickness of the Pennington formation at Osborn Gap could not be determined. The bottom of the highly colored shale is 300 feet below the base of the Lee, and it is underlain by 50 feet or more of sandstone. From the bottom of the Lee to the first limestone seen in the road is 700 feet vertically. Allowing for the dip of the rocks and grade of the road there may be 1,000 feet or more of the Pennington at this point.

LEE CONGLOMERATE.

Above the Pennington shale and immediately below the coal-bearing rocks there is a great thickness of heavy sandstones and conglomerate which is known in this part of the Appalachian region as the Lee conglomerate. In the Elkhorn field it has a thickness of 1,000 feet or more and is composed of thick beds of fine conglomerate at the top and bottom, with softer sandstone and shale and one or two small coal beds in the middle.

The Lee conglomerate is exposed all along the crest of Pine Mountain at the southeastern edge of this field, and also along Russell Fork from the Breaks to a little below the mouth of Elkhorn Creek. Elkhorn City is located directly on it, and the formation, which rises gradually toward the fault at the mouth of Grassy Creek. makes the walls of the gorge below that point. White, opaque quartz pebbles up to a quarter of an inch in diameter are common in the top and bottom members of the formation and give to it the name of "hailstone rock." The cementing material is not always strong and the quartz pebbles are abundant in the streams that flow off the formation. Along parts of the crest of Pine Mountain where the base of the Lee has been deeply weathered the surface is so covered with pebbles as to resemble the ground after a hailstorm.

The writer did not measure a section of the Lee. The base forms the crest of Pine Mountain, and the rest of the formation, dipping at an angle of 25°, is exposed on the eastern slope of the mountain in Virginia in such a manner that an accurate section can not be obtained. At the Breaks of Sandy the Lee is exposed in cliffs nearly 1,000 feet high (Pl. II, *B*, p. 14) and so nearly vertical as to be difficult of ascent. The formation as shown there appears to be composed very largely of sandstone.

A characteristic feature of the Lee conglomerate as noted in several places is the very strong cross-bedding within 50 feet of the top. This is well exposed at the lower end of the Breaks about 3 miles above Elkhorn City. Here between horizontal beds of coarse sandstone from 5 to 6 feet apart are sandstone strata a foot thick, dipping westward at an angle of 20°.

There are said to be two or three small coal beds in the Lee, but the writer did not see any in this district. It is reported on good authority that a 2-foot bed outcrops at the mouth of Grassy Creek and also in the gorge three-quarters of a mile below, but the former was not found when sought and the latter is said to be exposed at only low stages of the river.

COAL-BEARING ROCKS.

Immediately above the Lee conglomerate there is a series of sandstones and shales about 2,000 feet thick, which will be described in this report as the coal-bearing rocks, because they contain all the workable coals and because data has not been obtained sufficient for dividing them into formations. In the Estillville and Bristol folios of the Geologic Atlas of the United States, which contain descriptions of coal areas south of this in Virginia, rocks 1,200 feet thick overlying the Lee are called the Norton formation and are overlain by the Gladeville sandstone and Wise formation. It is probable that in the Elkhorn region rocks several hundred feet thick above the Lee belong to the Norton formation as described in Virginia, but the upper limit of the Norton was not definitely recognized, and as it is possible that there is considerable thinning of the formations in this direction it seems best in this reconnaissance report to make no attempt at a division of the coal-bearing rocks into formations. The name coal-bearing rocks in this report refers to the series of sandstones, shales, and coals which extend from the top of the Lee conglomerate to the highest rocks outcropping in the Flatwoods area.

The coal-bearing rocks form the surface of the entire region here described except a narrow belt along the north side of Pine Mountain. Short sections may be measured almost anywhere in the field, but sections of 600 or 800 feet can be seen to advantage only in the bluffs along Russell Fork. In the bluff at the mouth of Elkhorn Creek the rocks are exposed from the top of the Lee to the Lower Elkhorn coal, a distance of about 800 feet. Here, as elsewhere in the field, cliffs are formed by the massive sandstones.

A generalized section of these rocks made up from measurements taken in different parts of the field and averaged represents graphically (fig. 3) the sequence of the rocks. It should be understood that the sandstones are massive, thin-bedded, and shaly, and the shales are equally variable. Furthermore, the beds change in character as well as in thickness along their lateral extent. These facts necessarily make a section intended to represent the whole field merely a suggestion of the sequence of rocks which is not to be relied upon as everywhere true. The section shows that the lower 400 feet is more thin-bedded and shaly than the 600 feet lying next above;

and it makes plain that the upper 1,000 feet is more sandy and the beds are more massive than the lower 1,000 feet. Workable coal beds are largely in the lower half of the formation.

The bottom member is a 30- to 50-foot bed of dark shale which rests upon Lee conglomerate. The road from Elkhorn City to the Breaks is cut in this shale much of the way. Above it lies a 20-foot bed of massive, yellowish-gray quartzose sandstone, which is to be seen only on Russell Fork and the lower part of Elkhorn Creek. It makes a strong ledge which passes below water level just below the mouth of Beaver Creek. A coal bed averaging 30 inches thick and known locally as the Elswick bed lies on top of this sandstone.

Next above this is 60 or 70 feet of shale which carries large calcareous nodules. Some of these nodules are 1 to 3 feet in diameter. They occur at certain horizons rather than scattered through the whole shale bed. A section near the mouth of Moores Branch shows over 80 feet of this shale, but a short distance farther down the railroad there is a 10-foot bed of sandstone in the midst of it. The shale between the Elswick coal and this sandstone is almost black, of a somewhat lumpy character, and carries a few marine fossils.

A 40-foot massive sandstone occurs 150 feet above the Lee; then comes 50 feet of thin sandy beds and a 25-foot massive bed of sandstone, above which lies the Auxier coal. This coal is about 3 feet thick and is overlain by 160 feet of thin-bedded shales and sandstones, in the middle of which is sometimes found a 1-foot coal bed. The upper part of this interval may in places be occupied by massive rather than thin sandstones.

A coal which is at many places of workable thickness lies 160 feet above the Auxier coal, or 440 feet above the Lee conglomerate. This bed is opened at several points on the river below Ferrell Creek. For convenience in description, it will be called the Millard coal, for it has been opened at a number of places near Millard, at the junction of Russell and Levisa forks.

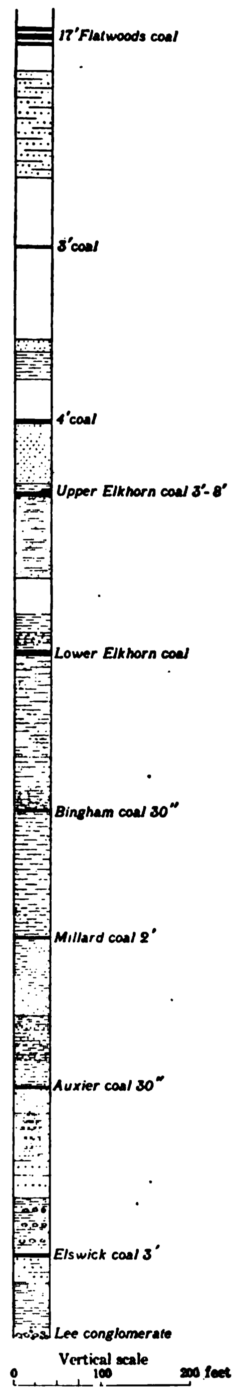


FIG. 3.—Generalized section of rocks above the Lee conglomerate.

Between this coal and the one next above, which will be called the Bingham bed, there is 150 feet of sandstone. The lower portion is thin-bedded and shaly, while the part just under the Bingham coal is massive. The Bingham bed is a little-known coal about 30 inches thick, which has been opened at only a few places. For convenience in description the writer has applied to this coal the name of a man living on the head of Ferrell Creek, who opened a pit on this coal several years ago. Sandstones, massive and shaly, to a thickness of 170 feet lie between it and the Lower Elkhorn coal, which is next above.

The Lower Elkhorn coal is found in this region about 800 feet above the Lee conglomerate. It is a bed of variable thickness, measuring from 3 to 8 feet. An average of 34 sections taken at as many different localities gives a thickness of 4 feet 3½ inches for the bed. The distance between the Lower and Upper Elkhorn beds is 180 feet, more or less. Shale or thin-bedded sandstone makes up the lower part of this interval, while rather massive sandstone occupies the upper half. This makes the Upper Elkhorn coal about 950 feet above the base of the formation.

The Upper Elkhorn coal is from 3 to 9 feet in total thickness. It averages about 4 feet in most of the area. This is the thickest of the workable coals occurring extensively throughout the field. Two beds reported as above the Upper Elkhorn are so high in the hills that they have been prospected but little, and exposures were not seen by the writer. One of these is said to be 80 feet and the other about 230 feet above the Upper Elkhorn coal. Each will yield an average thickness of 3 feet of coal.

Four hundred feet of rocks above the Upper Elkhorn coal are made up about equally of sandstone and shale. Then comes a massive, coarse-grained sandstone about 100 feet thick, which is exposed at the head of Cassell Fork of Marrowbone Creek. Its position is so high that it overtops the hills in a large part of the area here discussed, and is seen principally in the Flatwoods district. Like the Lee, it is very quartzose, has a gray weathered surface, and may possibly carry small quartz pebbles, although none were seen in the exposure on Cassell Fork. This sandstone is about 500 feet below the upland level known as the Flatwoods.

Above this sandstone lies a series of coal-bearing rocks 600 feet thick, which are found in the Elkhorn field only in the elevated region between the heads of Elkhorn and Shelby creeks. The detail of these beds, as measured by David White, is as follows: At the head of Cassell Fork a 17-foot coal bed, known as the Flatwoods coal, has been opened about 30 feet above the massive sandstone just mentioned. Above this coal is 100 feet of thin-bedded and 150 feet of

massive sandstone, some of which is strikingly pink on fresh fracture. The massive sandstone is overlain by 20 feet of shale, above which is a small coal bed. Above the coal is 110 feet of sandy shale with a band of limestone nodules near the top. Next above this, or 380 to 400 feet above the Flatwoods coal, is about 150 feet of massive sandstone, which forms a cliff around the edge of the Flatwoods area. A coal bloom was seen about 40 feet above this massive sandstone, and the highest rocks noted were sandy shale. A 4-foot coal reported[a] about 530 feet above the Flatwoods coal, close to the top of the hill, may be the one last mentioned.

STRUCTURE.

IMPORTANCE OF DETERMINATION OF STRUCTURE.

In the investigation of any coal field one of the principal questions to be answered is, What is the position of the coal beds; are they flat, folded, or strongly inclined from the horizontal? This knowledge is as important as a knowledge of the quality of the coal. In the first place, to the prospector a knowledge of the structure serves as a guide for tracing the outcrops of the beds. If the structure is flat, then the coal should be found at the same elevation on both sides of the hill or valley; if it dips, then the coal may be expected at a lower or higher elevation, according as the dip is with or opposed to the direction of advance. In the location of mines a knowledge of the structure of the field as a whole is invaluable for their successful development and operation. An outcrop entry or a shaft should be so located that there will be natural drainage to it; in other words, entry on a coal bed should begin at the lowest point. This is essential to facilitate drainage and the delivery of loaded cars from the breast to the mouth. Having a knowledge of the structure, an engineer can lay out his mine before breaking ground.

That the rocks do not lie flat in this field is seen readily by noting how the Elswick coal dips below the railroad at Moores Branch; it is shown by the way some coal banks drain in and others drain out.

METHOD OF DETERMINING AND REPRESENTING STRUCTURE.

The method usually employed in working out the structure of a coal field where the rocks have not been excessively disturbed is to select some conspicuous member of the formation and obtain its actual or relative elevations by aneroid, hand level, or spirit level at as many points as possible or necessary throughout the area. The relation of the reference stratum to any particular coal bed being known, and the interval between the beds being, presumably, practi-

[a] Crandall, A. R., Coals of the Big Sandy Valley: Kentucky Geol. Survey Bull. No. 4, 1905, p. 116.

cally constant over a limited area, the lay of the coal can be worked out from the elevations on the reference stratum. Structure may be represented by cross sections or by contour lines. The latter method gives the information much more completely than is possible with cross sections and is being commonly used. Contours are lines connecting points of equal elevation on an inclined surface. They show both the direction and rate of dip or inclination of the bed which they are intended to represent. The contours on the map (Pl. I, in pocket) are drawn from data on the map of the Elkhorn field made for the Big Sandy Company by E. V. d'Invilliers. In his survey D'Invilliers prospected for the Lower Elkhorn coal and obtained its elevation above sea level by vertical angles wherever it was found. With the information thus obtained, he represented the structure on his map by 20-foot contour lines. The structure given by D'Invilliers was checked as far as possible by the writer, and the result is much more accurate than any that could have been obtained with an aneroid barometer in the course of a reconnaissance survey. The map accompanying this report is on a smaller scale, and 50-foot contour lines are shown, practically reproducing the structure as determined by D'Invilliers, with some changes based on notes by the author. Elevations are based on a Chesapeake and Ohio Railway bench mark on a stump at the mouth of Marrowbone Creek, 736.99 feet above sea level.

CAUSE OF FOLDING.

Originally laid down flat, the rocks in the Elkhorn coal field are now inclined and slightly folded. This folding was produced by pressure or squeezing of the earth's crust. The position of the rocks where they have broken and one side has overridden the other indicates that the disturbance resulted from a lateral thrust from the east. Forty or more miles to the southeast, in the Great Appalachian Valley, the rocks are strongly folded and faulted, but from Sandy Ridge westward through Pike County the disturbance and crumpling is very gentle, except for the break along Pine Mountain. The effects of the lateral thrust die out westward until they become recognizable only by close leveling.

STRUCTURE OF THE COAL FIELD.

Pine Mountain marks a great break in the rocks forming the earth's surface. Along the north side of the mountain just under the crest there is a fault which raises rocks lying normally far below the coal formation to the surface and thrusts them up over the coal measures. How great the disturbance has been is shown by the position of the Lee formation, which is over 1,000 feet thick. The

top of this formation is just above water at the mouth of Elkhorn Creek, while the bottom of it, on the opposite side of the fault, has been shoved up until it marks the crest of the mountain at Blowing Rock and Pound gaps. In fact, at Blowing Rock the conglomerate, which is the base of the Lee formation and which is more than 1,000 feet below the surface at Elkhorn, is slightly above the gap.

The displacement at Blowing Rock Gap is probably more than 2,000 feet, but it may not exceed 1,000 feet at the Breaks of Sandy and seems to decrease rapidly from there northward, becoming perhaps merely a plunging anticlinal fold near the head of Grassy Creek.

Because of the drag of the overthrust, the rocks on the north side of the fault for a few rods are overturned. This can be seen in the Breaks of Sandy, where a diagrammatic section is shown in the rocky gorge. Rocks approaching the fault in a nearly horizontal attitude are turned up and over, and stand now at an angle of 70°. Farther south along the mountain these rocks seem to be overridden so far that their overturned edge is hidden beneath the mountain.

From the face of the fault scarp on Pine Mountain to Elkhorn Creek the rocks have a strong westward dip. Thence through the eastern Kentucky coal field there is a general decrease in elevation to the west. Although there is a predominant dip in one direction the rocks are slightly waved or folded, and these minor features rather than the general structure of the region are of the greatest importance to mining operations. It will be seen by the structure lines in red on the accompanying map (Pl. I) that the Lower Elkhorn coal, which is the surface represented by the contour lines, is 1,740 feet above sea level on the right fork of Beaver Creek, and is nearly 500 feet lower at the mouth of Russell Fork. Although the dip is very regular along the river there is a small basin or syncline extending from the head of Cassell Fork in a north-northwest direction to Daniels Creek and parallel with it an arch or anticline that can be traced easily from Shelby Gap to the head of Wolfpit Fork. In the western portion of the territory the dip is very regular to the west at 75 feet to the mile. The inclination of the coal beds scarcely exceeds 125 feet per mile in any locality.

The position of the anticline with relation to Marrowbone Creek is such as to facilitate mining operations on both sides of the creek, giving natural drainage and easy grades for haulage in the mines. The determination of structure in advance of actual mining is recognized to be of prime importance in the selection and development of coal properties.

CORRELATION OF ELKHORN COALS.

By David White.

The equivalents of the Elkhorn coals in the region to the northwest of the junction of Levisa and Russell forks of Big Sandy River have not been worked out completely. Owing to the snowy weather incident to the lateness of the season, field work in eastern Kentucky in 1906 was terminated before the geologic section had been carried to the Russell Fork basin so as to tie definitely with the key rocks of that area. The probable economic horizons were traced, both paleobotanically and stratigraphically, from the Kenova quadrangle on the Ohio River to Pikeville. Above Pikeville but little stratigraphic profiling was accomplished and but few fossils were collected for the reasons stated above. Consequently, in view of the incompleteness of the work and the lack of adequate data, I am obliged to propose only tentative and preliminary correlations, leaving the final and absolute determination or verification until the data may be sufficiently amplified through additional paleontologic or stratigraphic information.

Under the conditions prevailing at the close of the season it was possible to give but a portion of a single day to the collection of material from the Elkhorn coals in the Russell Fork region. This material, gathered from the upper and lower beds worked at the Pike mine, at the head of the railroad spur along Marrowbone Creek, leaves much to be desired, for although the material is richly fossiliferous the rock dump of the mine was so deeply covered with snow as to make collecting most difficult and inconclusive.

Although subsequent and more adequate collections may seriously modify these tentative correlations it appears probable from the paleobotanical data in hand that the upper bed at the Pike mine—the Upper Elkhorn—is the same as the coal worked on Ferguson Branch and Lower Chloe Creek near Pikeville. Similarly, the fossils obtained from the Lower Elkhorn coal at the Pike mine seem to represent the flora of the lower or Syck coal, worked for local consumption on Lower Chloe Creek near Pikeville. I expect that further paleobotanical work in the region will confirm these correlations, which must, however, for the present be regarded as provisional.

Assuming the reference of the Elkhorn coals to be correct the following correlations will obtain. The sandstone immediately or but a very short distance above the Elkhorn coal is a fairly well marked stratigraphic member, becoming very distinct in the region of Paintsville, where it overlies the Paintsville (or Prestonburg) coal and is clearly traceable to its point of disappearance near River station. The Ferguson Branch coal, which I believe to be the same

as the Upper Elkhorn coal, lies in the upper part of a thin band of shales carrying locally workable beds all the way from Pikeville to its disappearance below water level at River station. The Paintsville coal lies at the top and the coal worked at Harold and opened at several other points lies at the base of this thin belt of carbonaceous shales, which seldom exceeds 45 feet in thickness. To this horizon belongs the coal opened on Stonecoal Run at Wagner and at Hemlak. The heavy sandstone underlying this thin shale is continuous to its disappearance below Buffalo station, and throughout most of its exposure is characteristically massive, gnarly, and frequently in a very uneven basal contact with underlying blue argillaceous shales. It is finely exposed along Levisa Fork in the vicinity of Dwale, from which it might appropriately receive its name.

The Syck coal, to whose horizon I tentatively refer the Lower Elkhorn coal, lies above another heavy sandstone, well exposed in the banks of the river and along the railroad track at the lower end of Pikeville. To this sandstone, which first rises above the railroad track a short distance below the twenty-fifth milepost, or about 1½ miles below Pikeville, probably belongs a ledge showing in the sides of the valley below the level of the Lower Elkhorn coal near the Pike mine. Like the sandstone described above, it is readily susceptible of mapping to its point of disappearance.

Granting that the above correlation of the Elkhorn coals is correct, it becomes probable that the group of sandstones about 400 feet above the Upper Elkhorn coal in the slopes of the Flatwoods at the head of Marrowbone Creek is continuous with that associated with the Leslie coal near Pikeville and the old Peach Orchard coal in the vicinity of Richardson. I regard it as a member which may be readily mapped along Levisa Fork to its point of entrance into the Kenova quadrangle, where it falls within the Pottsville formation.

It was not practicable to attempt to determine paleobotanically the boundary between the Pottsville and the Allegheny formation in the Flatwoods region. I can only add that within the limited time available on the occasion of a hasty climb to the Flatwoods summit, the few fossil plants gathered from the roof of the great bed of coal known as the Flatwoods coal, which lies about 550 feet above the Upper Elkhorn coal, distinctly show the Pottsville age of the bed, referring it to the Kanawha formation, and leave no room for doubt as to the Pottsville age of the heavy sandstone ledge, 100 feet or more above the coal. No opportunity was offered to search for fossils in beds above this sandstone, but I am inclined to believe, in view of the age of the big coal just mentioned and of the probable expansion of the Kanawha formation to the eastward, that the sandstone forming the floor of the Flatwoods plateau and cropping out as cliffs

around the brow of that area may also be found eventually to fall within the limits of the Pottsville. If so, they will, perhaps, constitute the uppermost member of that formation.

The present state of knowledge does not justify a correlation of the Elkhorn with the coal beds in the Norton or Big Stone Gap region. It may, however, be remarked that the species of fossil plants from the Lower Elkhorn appear to bear a close relation to such material as I have been able to secure from the Banner group at Dorchester, near Norton.

The scanty paleobotanical evidence in hand indicates that the Elkhorn coals belong to the lower portion of the Kanawha formation, the Ferguson Branch (Pikeville) coal being probably at or near the horizon of the Peerless or Cedar Grove coals, on the Kanawha River.

The designation of the Paintsville coal as "Coal No. 1" and the application of numbers, such as "1" or "3," to the Elkhorn coals is both erroneous and misleading. Local names for the coals are far preferable in every way. The application of a numerical nomenclature to the beds is on all accounts to be discouraged locally and should be abandoned in all publications.

ECONOMIC GEOLOGY.

GENERAL CHARACTER AND OCCURRENCE OF THE COAL BEDS.

INTRODUCTION.

In this section the stratigraphic position and extent of each of the coal beds is described in order to give the reader an idea where each coal is to be found and how much of the territory it underlies, and to indicate the general features of its occurrence. In the succeeding section detailed descriptions of the various beds as revealed throughout the field by natural exposure, prospect trenches, pits, and mines will be given.

Correlations of the coal openings in this field have been so successful that it is possible to trace all of the workable beds with considerable certainty throughout the greater part of their extent in the region here discussed. For this reason it would be possible to make each coal bed the subject of a separate chapter, describing and comparing all the occurrences of that particular coal. It seems desirable, however, for the convenience of those who may make use of this report, and especially for those who may visit or live in the field, to describe under one heading all the coals in any one locality. By this method one can find what coals occur on any particular creek without examining several parts of the report. The description by localities has the disadvantage of not giving a continuous view of

any one coal bed, but this may be remedied somewhat by the grouping of sections of the same coal in one illustration.

ELSWICK COAL.

Lying 50 to 75 feet above the top of the Lee conglomerate and resting on a bed of massive sandstone from 20 to 30 feet thick is a workable bed known locally as the Elswick coal. Being stratigraphically the lowest of the coals in this field, the Elswick has the shortest outcrop. It rises above the waters of Russell Fork close to the mouth of Little Creek about 1 mile below Elkhorn City, and keeps above the river to the fault at Grassy Creek, a distance of 4 miles. It falls below the level of Elkhorn Creek between the mouths of Big Branch and Pond Branch, 1 mile above Elkhorn City. The horizon of this coal, therefore, underlies practically the entire field, but whether the coal exists and has a workable thickness elsewhere than in the immediate vicinity of the short outcrop just described is yet to be proved. If this bed is everywhere present beneath the surface of the field, which may be a reasonable supposition, and if it maintains an average thickness of 30 to 36 inches, then the tonnage of the Elswick bed is probably nearly equal to that of any other coal in the field. It may be considered as an available reserve, but will not be mined extensively so long as thicker beds outcrop in the same locality.

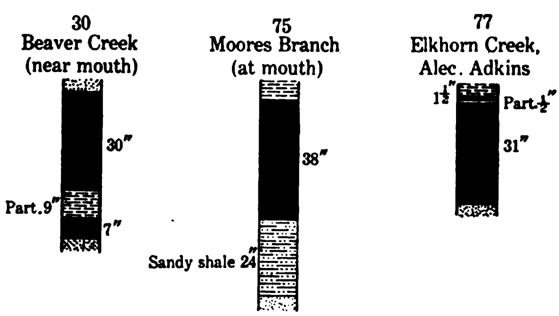


FIG. 4.—Elswick coal sections.

AUXIER COAL.

At a distance of 260 feet above the Lee conglomerate and about 500 feet below the Lower Elkhorn coal is the Auxier coal. It usually rests on a 30-foot sandstone more or less massive in character, and is overlain by shale. This bed has been found at frequent intervals along the creeks in this area and is recognized with some degree of certainty by its size and relative position in the geologic column.

If the correlation is correct, an 18-inch coal bed, said to occur in the bed of Russell Fork at the mouth of Biggs Branch, is the most northern outcrop of this coal in the Elkhorn field. Coal at the mouth of Lower Lick of Harless Creek and at Joe Looney's on Road Creek is believed to be the Auxier, and openings in the hol-

lows on the left of Ferrell Creek as far up as the schoolhouse at the mouth of Sprucepine Fork are tentatively assigned to the same bed. Continuing up Russell Fork prospects are found on Beaver Creek, Little Creek, and three-fourths of a mile up Moores Branch. The outcrop has been traced up Elkhorn Creek to where it goes under water just below Kettlecamp Branch, and although the coal was not seen on Russell Fork above Elkhorn City, the underlying rocks were traced to Grassy Creek and a coal which has been opened on Trace Fork one-fourth of a mile above Riley Cavin's place was recognized as probably being the Auxier. An average of 14 sections gives the bed a thickness of 2 feet 9 inches. The maximum is 4 feet 6 inches and the minimum 1 foot 8 inches.

MILLARD COAL.

This bed has been opened in several places near the confluence of Levisa and Russell forks and is known there as "The Forks" bed. Obviously this is not a desirable name to perpetuate, and the name Millard, which is the name of the post-office at the forks, is adopted for facilitating description and reference. The coal is 450 feet above the base of the formation and 300 to 350 feet below the Lower Elkhorn. It lies usually under a massive sandstone and on top of either sandstone or shale. Although the bed has an average thickness of 3 feet, the amount of available coal is barely 2 feet, on account of the clay partings.

The distribution of this coal in the area here described has not been determined so well as has that of the other beds. This is because it is unimportant, scarcely to be classed as workable, and therefore it has been prospected but little. It is possible that in a detailed survey of the region the outcrop could be traced, but in reconnaissance work of this sort it could not be mapped with thoroughness. The map (Pl. I, in pocket) shows the outcrop of this coal extending from Millard, along the river, up Powell Creek to Lick Fork, over a mile up Biggs Branch, and running up both forks of Daniels Creek. It is seen on Harless and Jimmie creeks, on Road Creek at Isam Fork and the mouth of Middle Fork, and on Ferrell Creek at the mouth of Bingham Fork. On Marrowbone Creek this coal is open in several places, and is best seen at the Marrowbone mine, where there is a pit a few rods east of the tipple. The coal also shows in the railroad cut near Johnson Fork. It was not seen on Elkhorn Creek.

BINGHAM COAL.

This coal was recognized by the writer as one not previously described. Its position is approximately 180 feet below the Lower

Elkhorn coal and in the midst of sandstone. It was first noted at E. B. Bingham's place, on Ferrell Creek, and later seen on Powell Creek and under the incline at the Marrowbone mine. The exposures are so few that a connected line of outcrop can not be shown on the map. The bed varies according to 4 sections from 2 feet 6 inches to 4 feet 5 inches in thickness.

LOWER ELKHORN COAL.

Thorough prospecting for this bed in all parts of the field by both residents and investors has brought to light more information concerning the Lower Elkhorn than any other coal in the region. Prospect trenches have been cut to the crop at short intervals in much of the field, small pits kept open by timbering are plentiful, and five mines show the character of the bed under cover. Under these conditions it can be traced from point to point with considerable certainty. The line on the map representing the outcrop is taken from the map of d'Invilliers and is considered accurate, part of it having been run by stadia. On the map (Pl. I) the boundaries of coal areas where shown by solid lines are regarded as more accurate than where shown by dotted lines.

The Lower Elkhorn coal is between 750 and 800 feet above the Lee conglomerate. As described in the chapter on stratigraphy, it usually crowns a more or less massive sandstone, which may be from 20 to 60 feet thick, and it is overlain by shale or thin-bedded sandstone. The underlying sandstone serves in some places as a guide to the location of the coal, making a ledge on top of which the coal should be found.

This coal is always high above the main drainage and passes below water level only close to the heads of the streams. Its altitude above Russell Fork is from 500 to 800 feet, and as the dips are not strong the outcrop extends up the side valleys to their very heads. As will be seen by the accompanying map, the outcrop of the coal delineates every valley, and is found throughout the field except on the south side of Elkhorn Creek. For this reason no further description of the distribution is deemed necessary. Although the coal is several hundred feet above the river, it is not so high but that the hills rise considerably above it and leave an extensive body of coal with considerable cover. The Lower Elkhorn bed appears to be of workable thickness throughout the field, averaging over 4 feet. There is, however, a feature of this bed, so common in most of the field as to be characteristic, which greatly reduces its value from a mining standpoint and leaves only three-fourths of the bed to be reckoned as available fuel. This unfortunate feature is the so-called laminated coal.

"Laminated" is a term applied to bony coal which is composed of alternating lamellæ of bone and bright coal. The streaks of bone

give strength, so that it mines in hard, flat slabs, but they also make it high in ash. In the Elkhorn field the term is applied also to the soft, flaky, slickensided coal which emits a dull sound when struck and which breaks into small chips when mined. The true laminated and the crushed flaky coal occur commonly in the Lower Elkhorn bed in this field and are found also in the Upper Elkhorn bed.

Bony and flaky coal usually forms the upper part of the Lower Elkhorn bed, but it may be in the middle and overlain by solid block coal. The flaky, crushed material usually exceeds the bony coal in thickness. In this report the term "laminated" coal refers to the bony, flaky portion of the beds, in accordance with the usage in the field described.

The soft and flaky portion of the Elkhorn beds breaks into chips, which have many smooth, polished surfaces; it may have schistosity developed in it parallel or oblique to the normal bedding, and in places is rolled and twisted into a rumpled mass, which is strikingly different in appearance from a normal bed of bituminous coal. It appears to have been subjected to crushing between laterally moving strata, and in that respect resembles the Widow Kennedy coal bed as exposed at Dante and other places in Virginia. The crustal strain which found relief in the Pine Mountain fault probably was partly taken up in the Lower Elkhorn coal. Whether the overthrust at the fault produced a single westward movement of a few inches in the beds down to the Lower Elkhorn coal or whether the movement was a forward-and-back jarring motion is not certain, but it seems plausible that the broken condition of the upper part of this bed was produced by slight lateral movement of the overlying beds.

The laminated coal ignites quickly and burns readily under a strong draft, but it is high in ash, and for that reason and because so much of it breaks down to slack on handling it is undesirable as a steaming coal. The experience of the companies operating on Marrowbone Creek has been that the inclusion of the laminated coal in run-of-mine shipments was objectionable to their customers, as it gave them a fuel with an undesirably large amount of slack and clinker.

The common section of this bed on Marrowbone Creek is 30 to 36 inches of solid coal overlain by 9 to 20 inches of laminated coal. If the lamination is due to movement, it would be natural to expect that it would disappear to the west with increasing distance from Pine Mountain fault. The evidence on this point noted by the writer is that the greatest thickness of laminated coal is on Big Branch of Elkhorn Creek, which is near the fault, and that there is little or no lamination apparent in the few openings seen on Rockhouse and

Wolfpit creeks. A coal, probably corresponding to the Lower Elkhorn, mined in the John Robinson bank on Pompey Creek 2 miles north of Millard, shows no lamination.

UPPER ELKHORN COAL.

The position of this bed is from 160 to 190 feet above the Lower Elkhorn or 900 to 1,000 feet above the Lee conglomerate. It is in a portion of the geologic column that is made up largely of heavy-bedded or massive sandstone. Geographically it is located in the high land, being from 700 to 900 feet above Russell Fork, and therefore near the tops of the ridges along the river. Between Russell and Levisa forks this coal occurs only in long narrow bodies in the crests of the divides, but west of Russell Fork the dip of the rocks brings the coal down so that it underlies broad areas between Shelby, Marrowbone, and Elkhorn creeks. It can be found throughout the entire region by going high enough on the hills.

East of Russell Fork, in the vicinity of Ferrell Creek, the Upper Elkhorn coal ranges from 5 to 7 feet thick, with only 4 to 8 inches of waste. On Marrowbone Creek 9 sections give an average of 3 feet 10 inches for the thickness of the bed, and 3 feet 2 inches of this is the average amount of marketable coal. The range in thickness of the whole bed on this creek is from 2 feet 10 inches to 5 feet and of the solid coal from 2 feet 5 inches to 4 feet 4 inches.

At the head of Elkhorn Creek, where the Upper Elkhorn attains extraordinary development, the thickness of the entire bed at 7 localities ranges from 7 feet 8 inches to 9 feet 4 inches, with an average of 8 feet 7 inches. The amount of marketable coal in this bed around the head of Elkhorn Creek averages 7 feet 9 inches.

Twenty sections from all parts of the field give the Upper Elkhorn an average thickness of 6 feet, but the average amount of marketable coal is only 5 feet 4 inches. It should be borne in mind, however, that 7 of these sections are from a very small part of the field where the bed is exceptionally large. The other 13 sections, which represent more nearly the normal condition through much the greater part of the field, gives an average thickness of 4½ feet for the whole bed.

FLATWOODS COAL.

The Flatwoods coal is approximately 1,500 feet above the Lee conglomerate. Its altitude is so great that it occupies only two small areas of the greatest elevation in the field. The larger area, which has an irregular shape, lies at the head of Marrowbone Creek and the smaller one is at the head of Poorbottom Creek. They contain about 2,300 acres. The thickness of the bed around the head of

Cassell Fork varies from 14 to 18 feet. Only the upper 7 feet of the bed can be mined advantageously, the lower portion being in large part heavy bands of clay.

DETAILED DESCRIPTIONS.

INTRODUCTION.

In this section the occurrence of the coals as they are exposed in natural outcrop, prospect trenches, pits, and mines, is fully described. The description of the coals is arranged by creeks. Each coal bed in a creek basin is discussed separately, beginning with the lowest. As descriptions of the creek areas do not include a few exposures along Russell Fork, these are given under the heading of the nearest main creek on the same side of the river. That part of the field on the east side of the river is described first. It is customary in this region to speak of the branches and sides of a stream as "right" or "left" as they are encountered in going *upstream*, and that usage is followed in this report.

The graphic sections are arranged in groups, so that all sections of any one coal, as far as possible, are in the same figure.

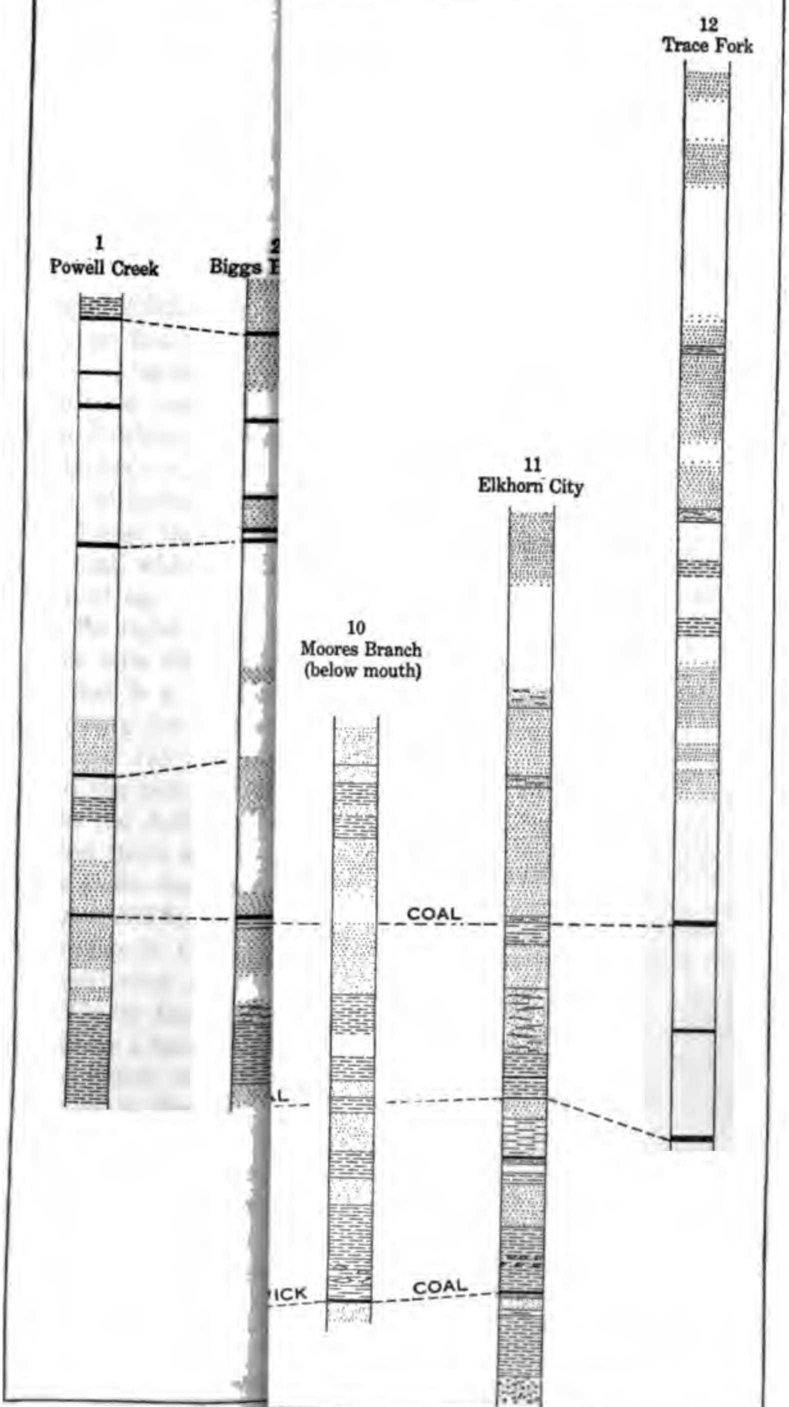
POWELL CREEK AND MILLARD.

Geologic section.—The rock exposed at water level from the mouth of Powell Creek to Millard, or "The Forks," is shale, which is believed to lie close above the Auxier coal. The Millard bed is about 175 feet above the river and is in the midst of 100 feet of sandstone. On Powell Creek a coal bed of which little is known is found 130 feet above the Millard, and the Lower Elkhorn appears to be 340 feet above the Millard. Above the Lower Elkhorn at vertical distances of 125 and 200 feet there are coal beds of workable thickness. A partial section of the succession of rocks in this vicinity is given in the columnar section sheet (Pl. III).

Millard coal.—At the forks of Big Sandy, where this bed is called "The Forks" coal, there is an old pit in the hill above Al. Huffman's house on the northwest side of the river about 175 feet above the water. It was opened many years ago and is still accessible because the overlying sandstone ledge makes an excellent roof. Coal has not been mined here for some years, the supply for the neighborhood being hauled from Pompey Creek. The bed (1)[a] lies between massive sandstones and shows 23 inches of coal with a few inches of shale above and below.

An opening once made on this coal back of J. W. Ford's store, which is also Millard post-office, at an elevation of 175 feet above the river, is caved, but is reported to have shown 2 feet of coal. Three

[a] A number in parenthesis refers to the number of a graphic section in a figure and to the location of the same section on the map.


12
Trace Fork
1
Powell Creek
2
Biggs
11
Elkhorn City
10
Moores Branch
(below mouth)
COAL
COAL

old openings near the schoolhouse between Millard and the mouth of Powell Creek developed from 26 to 28 inches of clear coal. The Millard bed varies slightly in thickness on Powell Creek. According to report it is 22 inches thick in a small draw on the left, about one-fourth mile from Polley's store, and a little above the mouth of Lick Fork is 18 inches thick (2).

Bingham coal.—Farther up the main creek on the right hillside, just above Mrs. Hunter's, is an entry driven in 40 feet under a sandstone roof which shows (3) a 3-foot bed.

Lower Elkhorn coal.—In the first hollow on the left of Mead Fork, one-fourth mile beyond and 200 feet above Mrs. Mead's house, there is a bank from which coal has been taken recently. It is at an altitude (aneroid reading) of 1,300 feet and is regarded as the Lower Elkhorn. The drift has been driven about 40 feet S. 70° E. and drains out. The roof is sandstone and the floor shale, and the bed is 40 inches thick (4). Laminated coal from 13 to 16 inches thick forms the upper part of the bed and is separated from the block coal, which is from 23 to 26 inches thick, by a one-fourth inch bone parting.

On the right bank of the main fork of Powell Creek about three-fourths mile above the mouth of Mead Fork and at an elevation of 1,300 feet is a pit opposite a cabin. The coal has been dug along the outcrop for 15 feet, showing a sandstone roof, 15 inches of laminated coal (5) and 20 inches of the lower bench. The whole thickness of the bed was not seen. This is a very different section from that in the John Robinson bank on Pompey Creek, where the bed is 4 feet thick and is all solid block coal except 4 inches of bone 10 inches above the floor.

Upper Elkhorn coal.—On the same side of the branch and 135 feet higher in the hill is a prospect which shows 2 feet 8 inches of solid coal with a one-fourth inch clay streak a little above the middle. Thirty feet above it is a 6-inch coal and 50 feet higher a prospect shows a bed over 4 feet thick (6). Whether this bed or the one 80 feet below it is the Upper Elkhorn is not certain. At the head of the main fork an old bank belonging to D. C. Potter is partly caved, but it shows 3 feet 2 inches of solid coal and 4 inches of bone at the base. This bank is said to have been open twelve years and to have two rooms driven east and northeast which drain out. The elevation is the same as that of the 2-foot 8-inch bed farther down the creek, 1,440 feet above tide, and it is supposed to be the Upper Elkhorn.

BIGGS BRANCH.

Millard coal.—Openings on the Millard coal were once made in the hill pasture 180 feet above Jim Goff's blacksmith shop, and also at

Winwright's, on the west side of the river opposite Goff's. Four feet of coal is reported in each of these, but the measurement could not be verified, as the coal is hidden by the caving of the banks. Little more than a mile up Biggs Branch the Millard coal has been dug on both sides of the creek a few feet above the stream. On the left a semi-

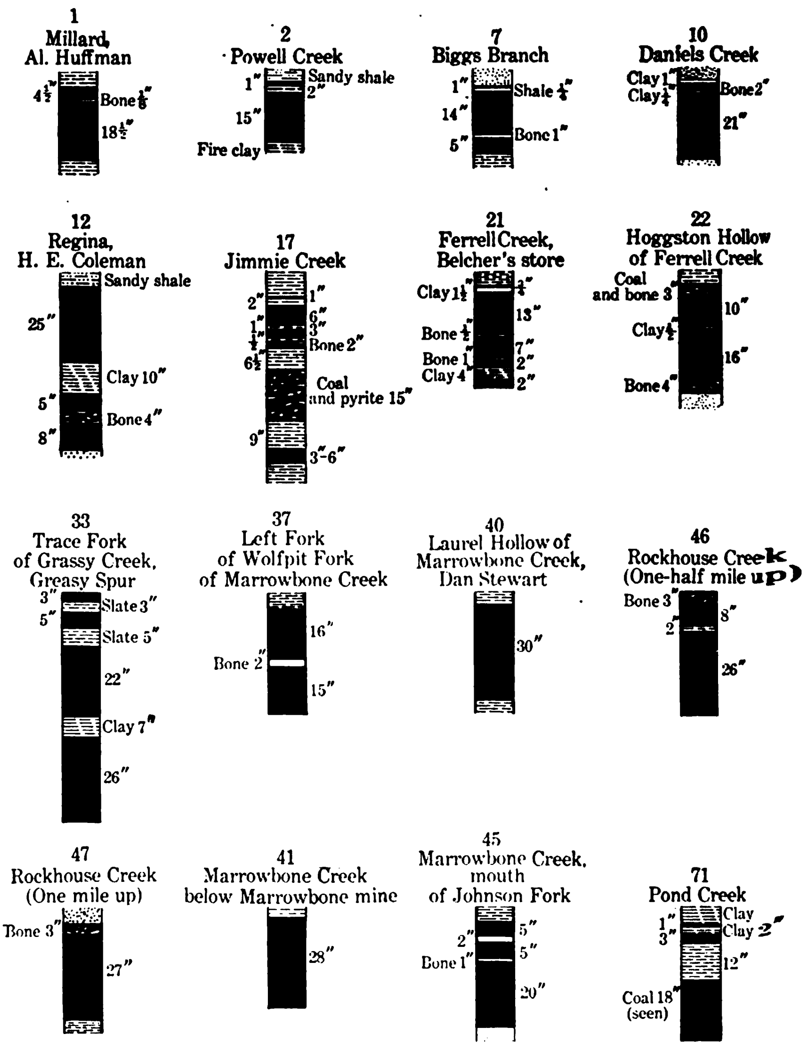


FIG. 5.—Millard coal sections.

circular opening 30 feet long and 20 feet deep shows a 21-inch bed (7) of coal with a shale floor and sandstone roof. In the right bank the bed has the same thickness, and three or four pits within a distance of 50 yards along the crop have been driven in 20 feet.

'lkhorn coals.—Two miles up Biggs Branch, on the right bank ind Isaac Lee's cabin, which is at the forks, and about 150 feet ve the cabin, there is an interesting occurrence of a double bed ›oal which is at about the horizon of the Lower Elkhorn. The spect on this coal is driven S. 10° W., is timbered, and drains in. › section of the entire bed (8), beginning at the top, is as follows: y, soft and dirty coal, 16 inches; block coal, 2 feet 2 inches; shale, eet; coal, 2 feet; bony coal, 7 inches; shale floor. No similar .ion was seen anywhere in the field. On the right side of the left k and 30 feet higher than the double coal just described a trench eals a bed (9) nearly 5 feet thick and mostly bone. Below the tom clay is coal and bone of undetermined thickness. This sec- ı may improve on driving in.

n the same hollow as the last and 70 feet above it a trench shows ›et 6 inches of coal, and on the opposite side of the spur, 80 feet her than the prospect just mentioned, or at an elevation of about !0 feet, there is a 4-foot bed, which is all coal except a 4-inch shale d 8 inches above the floor. The position of this bed corresponds h that of the 50-inch bed (6) in Powell Creek, and the 2-foot ıch coal here with the 2-foot 8-inch on Powell Creek. It will be ı by the section of the exposures in this branch given on the colum- section sheet (Pl. III, sec. 2) that the double bed at Lee's is the .e distance above the Millard coal as is the Lower Elkhorn on vell Creek, and that each section has a coal bed not found in the ›r.

DANIELS CREEK.

'illard coal.—The presence of this coal on the left fork of the ›k was reported, but search at that point failed to reveal anything]he pit said to have been dug close to water level. On the right ‹ at an elevation of 975 feet, or 160 feet higher than the forks, on a trail along the left hillside, Mose Coleman has a small open- ‹on the Millard coal which lies between beds of sandstone. It has ›nches of coal with 2 inches of bone for a roof (10).

‹ower Elkhorn coal.—The only opening on this coal known on ıiels Creek is a prospect driven by Elijah Anderson in the right k just above water and close to his house, which is at the head of]eft fork. Here over the usual sandstone is a bed of coal more ı 4 feet thick (11) and separated from an overlying sandstone by ›et of shale. Twelve inches of laminated coal lie above a 2-foot ch of solid coal. Mr. Anderson reported 4 inches of bone and 1 t of coal occurring below the 2-foot bench. The elevation of this ›ning, obtained by aneroid, is 1,300 feet, and shows the continua- n of the syncline on the north side of the river.

HARLESS CREEK.

Auxier coal.—Probably the oldest coal bank in this vicinity is one opened by Buck Hilton about thirty years ago on land belonging to Butler Ratliff situated on the main fork of Harless Creek between Upper Lick and Lower Lick. It is just above water level on the right bank and 1¾ miles from Regina. A demand for coal for a dinky locomotive which was hauling logs out of Harless Creek was the reason for opening the bank. A chamber about 30 feet wide was excavated and the roof was supported by timbers, but these are giving away and the bank is in danger of caving. The roof and floor are shale. Some coal was taken from this bank in the winter of 1906. The section of the bed (13) resembles more closely the Millard coal opened at Coleman's one-fourth of a mile below Regina than it does any of the sections of the Auxier, but its position as determined by road sections and the interval between it and the Lower Elkhorn on Lower Lick lead to the conclusion that this much-parted bed is the Auxier.

Millard coal.—About 1½ miles below the mouth of Harless Creek, on the left side of Schoolhouse Hollow, perhaps 200 yards from the road, there was once an opening and chute at the Millard coal, which is reported to be 2 feet thick. It is at an elevation of 175 feet above the road, or 980 feet above tide, rests on 60 feet of sandstone, and has a shale roof. The general structure along the river is shown by the gradual rise of this coal bed toward the east.

Probably the largest pit yet opened on the Millard coal is that from which H. E. Coleman has taken fuel for the past ten years. It is situated on the right side of the hollow which opens at his house, opposite Marrowbone station, at an elevation of 250 feet above the river, and is reached by a haul road. The bed lies on 50 feet of heavy sandstone and has a sandy shale floor. It is 4 feet 4 inches thick (12), and the coal is in three benches. A drift has been driven 125 feet S. 25° E. This bed is exposed farther up the hollow at the stable built by David Sanders. An analysis of the Millard coal, made from a sample taken by the writer at the Coleman bank, is given on page 72.

Bingham coal.—An 18-inch bed, which carries considerable iron pyrite and outcrops in the bed of Harless Creek at Will Ward's house, is believed to be at the same horizon as the 3-foot coal at Hunter's, on Powell Creek, and at Bingham's, on Ferrell Creek. Its position is 160 to 180 feet below the Lower Elkhorn coal.

Lower Elkhorn coal.—Four openings on this coal were found on Harless Creek at elevations ranging from 1,320 to 1,400 feet. One at the head of Righthand Fork was opened in the hillside above David Coleman's cabin in 1904. The pit is 20 feet wide and 15

feet deep, timbered, and driven southeast. It shows 15 inches of laminated on top of 4 feet of solid coal (16).

On Lower Lick of left fork a trench shows the bed 5 feet thick. This prospect can be found by going up the bed of the branch about one-fourth mile and climbing the right hillside at a point marked by a tree blazed SR. The upper 18 inches of the bed at this point looks like cannel coal (15). This bed has been prospected on the left side of Corn Hollow at an elevation of 1,320 feet and shows a thickness of 3 feet 3 inches. At the left side of Mose Coleman Hollow, which is the first on the left above Will Ward's, a pit opened thirty years ago also shows the bed 3 feet 3 inches thick and dipping west. The upper 15 inches of the bed is laminated.

Upper Elkhorn coal.—This coal was seen in Mose Coleman Hollow, at the head of Harless Creek, in an old pit on Butler Ratliff's land. It measures 5 feet (14), with only one parting, but that is rather thick.

JIMMIE CREEK.

Millard coal.—On Ratliff heirs' land, about 1¼ miles above the mouth of the creek, there is a coal bed which, from its geologic relations and elevation of 1,050 feet, seems to be the Millard. It lies between the usual beds of sandstone, but it is much thicker here than elsewhere, owing to the presence of shale partings. Section 17, fig. 5, shows the character of the bed.

Sixty feet higher there is a bed in the creek below Thomas Ratliff's cabin showing over 15 inches of coal. It has a shale roof and thin blue clay floor resting on sandstone.

Elkhorn coals.—The Elkhorn coals have not been prospected on this creek, and so nothing was seen of them. The Upper Elkhorn lies well below the summit of the ridge around the head of the creek, but the ridge is so narrow and steep near the top that the remaining portion of the coal bed has only a small area.

ROAD CREEK.

Geologic section.—The meager section obtained on this creek shows the Auxier coal a little over 100 feet above the river, but rising rapidly in the first half mile up the creek. Two hundred feet above it is the Millard, and 320 feet higher is the Lower Elkhorn. The interval between the last two coals is practically the same as in Powell Creek and Biggs Branch. The bloom of the Bingham coal was seen about 120 feet higher than the Millard on Isam Fork. Section 5, Pl. III (p. 38), is a partial representation of rocks on this creek.

Auxier coal.—Several openings, supposed to be on the Auxier coal, have been made at Joe Looney's, 1 mile up the creek. One bank has a 25-foot drift run N. 30° W., which dips into the hill and is full of

water. The bed rests on sandstone and has a shale roof. Only 2 feet of coal could be seen in the flooded opening, but it is reported that at this, as well as other openings close at hand, there are 3 feet of coal. The rocks dip strongly to the west on lower Road Creek.

Millard coal.—Road Creek shows two openings which are presumed to be on the Millard coal. One of these exposures is on Isam Fork by the roadside, a short distance from the mouth of the fork. It shows a sandstone roof, 1 inch of coal, 3 inches of clay, and 22 inches of coal. The other opening reveals the same thickness of bed under a sandstone ledge opposite Marshall Farmer's house, at the mouth of Middle Fork. Its elevation is 1,072 feet.

Lower Elkhorn coal.—As there are several pits on this creek which are timbered and kept open, so that coal can be taken every winter, the character of the bed is easily studied. In every case the roof is shale, and the floor, which could not be seen so readily, probably is bone closely underlain by sandstone. The pit nearest the river is that of Robert Martin, 1,480 feet above sea, at the head of a branch which enters Road Creek on the right less than three-fourths mile above the mouth. This bank has been driven 40 feet N. 45° W., but it drains in. The bed (20) is 15 inches laminated and 4 feet 1 inch solid coal. A sample of the solid coal was taken by the writer, and its analysis is given on page 72.

At the head of Coalbank Hollow Alex Hackney has dug a 20-foot drift N. 75° E., and timbered it. The bed is 1 inch thicker than at Martin's, the increase being in the solid coal. Around the next spur in the head of Cotton Patch Hollow, on John T. Ratliff heirs' land, a drift of about the same size and at the same elevation, 1,465 feet, shows just 5 feet of coal, the top 15 inches of which are laminated. Marshall Farmer has an opening in the left bank at the head of Middle Fork, half a mile above his house, where the bed (19) has the greatest thickness found on the creek. At the face of the drift, which is 30 feet deep and driven N. 15° W., the bed shows a total thickness of 5 feet 10 inches, 14 inches of which are laminated. Its elevation is 1,450 feet. An opening on the left side of Main Fork, one-half mile above Marshall Farmer's, is caved so that the full thickness of the bed could not be determined, but the usual 15 inches of laminated coal was visible. The last bank to be described on this creek is that of H. G. Belcher, at the head of Isam Fork. The coal is at an elevation of 1,420 feet, over 40 feet lower than on the right side of the creek at Hackney's bank, showing a westward dip of the rocks. The Belcher pit is driven east 10 feet and exposes 5 feet 4½ inches of coal. An increase of the laminated to 17 inches is noted here, also the ocurrence of a one-half inch clay parting 2 feet 3 inches above the floor. In the lower bench there are three or four thin partings, not shown in the section (18, fig. 9), which come and go irregularly.

These notes show that the Lower Elkhorn bed on Road Creek, excluding the laminated portion, averages fully 4 feet of available coal.

The Upper Elkhorn coal is so high in the ridge that there is only a very narrow body of it between Road and Jimmie creeks. No openings on it were seen.

FERRELL CREEK.

Geologic section.—The Elswick coal probably is not more than 60 feet below the surface at the mouth of Ferrell Creek, for the Auxier coal is found 130 feet above the river. One hundred and sixty feet higher is a 22-inch coal supposed to be the Millard, and 125 feet above that a 2½-foot bed, here described as the Bingham. The Lower Elkhorn occurs about 300 feet above the Millard, or at elevations ranging from 1,480 to 1,600 feet above tide as the creek is ascended. The dip along this creek in a general way is strongly northwest. The Upper Elkhorn is 150 feet above the Lower and well toward the tops of the hills. On Pl. III (p. 38) is a section compiled from measurements on this creek.

Auxier coal.—On Middlefield Branch, on George Belcher's land, there is an old opening about 80 feet above the mouth of the hollow, in which 2 feet of coal is reported. The rocks rise up Ferrell Creek and at the schoolhouse just below Sprucepine Fork this coal shows 15 feet above the creek. The coal is 22 inches thick and has a blue shale roof. It has been dug along the crop for 100 feet to get fuel for the school.

On Board Fork, one-half mile above Ferrell Creek, there are 3 old openings on John Belcher's land. One of these is an entry driven S. 40° W., down the dip. A small amount of coal has been mined from the bed, which is reported to be 3 feet thick. The same bed was once opened at Marion Spear's on Shop Branch and is said to carry 3 feet of coal. In both of these places the roof is shale and the bed is on top of a considerable thickness of sandstone.

Millard coal.—There is an old bank in the first hollow on the west above George Belcher's store at the mouth of Ferrell Creek at an elevation of about 225 feet above the river. The bed rests on heavy sandstone and has a shale roof. It carries 2 feet of coal, but is broken by shale partings, the thickest of which is 4 inches (21). In Hoggston Hollow, at an elevation of 1,100 feet, or 200 feet above Ferrell Creek, is a little bank on the Millard coal, owned by George Belcher. It shows 2½ feet (22) of coal, and has a shale roof and sandstone floor. A coal at water level in the bank of this creek at the mouth of Bingham Fork, said by L. B. Roe to be 22 inches thick, is also believed to be the Millard.

Bingham coal.—Another and a higher coal, perhaps 125 feet above this last, has been opened back of E. B. Bingham's cabin, one-half

mile up Bingham Fork. It is called a 2½-foot bed, but the bank was caved when the locality was visited, and the report could not be verified. The writer gave the bed its name, because the coal was first recognized and determined here, where the Lower and Upper Elkhorn coals are opened in the same hillside and the intervals between the three coals are easily measured. This coal at Bingham's rests on 40 feet of sandstone and is about 180 feet below the Lower Elkhorn coal.

Lower Elkhorn coal.—Prospect trenches driven to the Lower Elkhorn coal on this creek have in most cases fallen in, and consequently the elevation but not the character of the bed can be obtained. An old prospect at the head of Hoggston Hollow shows that the bed is at an elevation of 1,490 feet, or about 700 feet above the river, while the Clevinger bank, also caved, near the head of the creek, is 100 feet higher, showing the rise of the rocks to the east. A good opening is that of Arch Hoggston, a few hundred yards back of his house, at the right head of Middlefield Branch. The bed is at an elevation of 1,473 feet, has a 3-foot roof of sandy shale overlain by sandstone, and measures 5 feet 2 inches thick. The bed is made up of 14 inches laminated and 3 feet 11 inches of solid coal with a 1-inch clay parting 14 inches above the floor.

On Sprucepine Fork at an elevation of 1,540 feet, on the spur between the main branches, a prospect trench was cut in August, 1906, which shows the bed to be 8 feet 4½ inches thick. This is an unusual thickening, and is due, as is the increase at almost every opening on Ferrell Creek, to the addition of a clay parting and another bench of coal to the bottom of the bed. The section in detail at this opening, which is on George Belcher's land, is: Laminated coal 16 inches, "mother coal" one-fourth inch, coal 17 inches, "mother coal" one-fourth inch, coal 18 inches, clay 20 inches, coal 29 inches. At the right head of a small branch which enters the main stream at Richard Epling's, one-third mile below the gap leading to Road Fork, a bank has been driven 25 feet N. 35° E. The bed is 5 feet 9 inches thick (27) with 1 foot of clay shale separating it from the overlying sandstone. The laminated portion is only 12 inches thick.

Abners Fork is the site of several openings in which the bed has a thickness of over 6 feet. An opening made at the head of the first left fork at an elevation of 1,490 feet is reported by J. W. Church to have revealed 6 feet of coal. L. B. Roe's bank (23) at the head of Abners Fork is driven 75 feet in a southeast direction. Timbering keeps it open so that coal can be mined every winter. The laminated coal 15 inches thick is not mined. Under it is 4 feet of coal, then 6 inches of clay, and a bottom bench of 14 inches of coal. This section differs from that at another opening (24) on Roe's land across the creek from the above and at the same elevation, 1,465 feet, where the

bottom bench of coal is 3 inches thicker and the clay 3 inches thinner. On the right branch of a hollow which enters Bingham Fork at E. B. Bingham's cabin a coal bank has been drifted in about 15 feet. The bed (25) is 6½ feet thick, and has 16 inches of laminated coal at the top.

Upper Elkhorn coal.—A newly faced trench at Bingham's, 150 feet above his bank on the Lower Elkhorn, showed 75 inches of coal in an unbroken bed (26) at an elevation of 1,680 feet. On the right fork of Sprucepine Fork a prospect opened by George Belcher shows the Upper Elkhorn 7 feet thick (28). A prospect at the head of Abners Fork, 160 feet above (24), at an elevation of 1,640 feet, found the Upper Elkhorn coal, but caving had concealed the bed so that it could not be measured. J. W. Church reports that this coal at the head of the hollow back of his house is about 4 feet thick and at the head of Honey Fork is 6 feet thick.

BEAVER CREEK.

Geologic section.—The geologic section on this creek begins with the sandstone under the Elswick coal and extends more than 100 feet above the Upper Elkhorn coal. Nothing was observed of the upper part of the section, so the figures on the columnar section sheet only partially represent the stratigraphy of Beaver Creek. It will be seen that the Auxier coal is about 190 feet above the Elswick and that the correlation and elevation of coals above this is uncertain. This is due partly to the fact that no exposures of the upper coals were found except one at the head of the creek. The rocks rise rapidly up Beaver Creek, but the writer is skeptical about the position of the Lower Elkhorn being so high as is indicated on the Big Sandy Company map.

Elswick coal.—Close beside the schoolhouse at the mouth of Beaver Creek at an elevation of 821 feet above tide there is an exposure of the Elswick coal. The roof is 2 feet of sandstone overlain by shale and the floor is sandstone. There are two benches of coal, the upper 28 to 30 inches and the lower 7 inches, with an 8- to 9-inch shale parting between them (30). On the river a few hundred yards above the mouth of Beaver Creek this coal in a small opening shows 1 foot of clay between it and the underlying 25-foot sandstone and has a shale roof. The bed is a trifle thinner, having 32 inches of coal underlain by 2 inches of bone and 6 inches of coal.

Auxier coal.—In the hollow one-fourth mile below Beaver Creek, Ryus Roberts takes out a little coal every winter from a bank driven about 75 yards S. 45° E. The roof is blue shale and the floor black slaty rock. Solid coal 2 feet 7 inches thick is found in the bank (29), but it increases to 3 feet at the outcrop. There is a prospect above the first left fork of Mud Lick Branch of Beaver Creek on the land of

Enoch Belcher, which shows a shale roof, 4 inches of coal, 5 inches of clay, and 1 foot of coal at the bottom of the prospect. This lower bench is said to be 3 feet thick.

The blossom of the Auxier coal was found in measuring a section at a small branch one-half mile up Beaver Creek at an elevation of 170 feet above the road. An opening made years ago but closed now could readily be reopened back of the house at the mouth of Stonecoal Branch. Two and one-half feet of coal is said to have been found here. The writer is in doubt whether the coal opened on both sides of the creek at Babe Potter's, just above the mouth of Left Fork may not also be Auxier. A hurried tracing of the rocks along the creek seemed to indicate that the coal at the mouth of

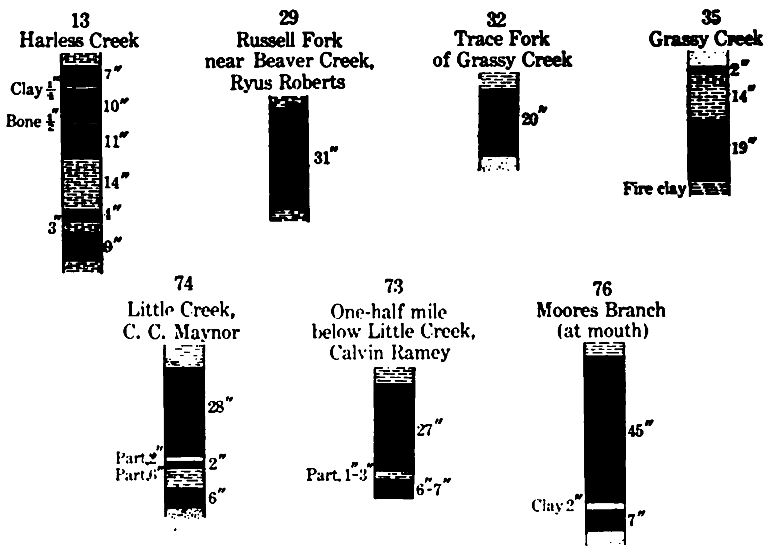


FIG. 6. —Auxier coal sections.

Stonecoal Branch passes below the creek near the mouth of Flat Fork, but it is possible there is sufficient inclination of the rocks to keep it above water for some distance upstream. The opening opposite Babe Potter's is closed, but one back of the cabin shows a shale roof and 2½ feet of coal. The floor was hidden by water, and a lower bench of coal reported by the owner was not seen. The same bed has been dug into on the Left Fork just above the mouth.

On Right Fork, in a hollow back of Mrs. Elizabeth Ramey's place, coal has been dug from a small bed, which is 140 feet above the coal at Babe Potter's, but seemingly not high enough for the Millard coal. At the mouth of Bear Fork, 90 feet above the creek, Enoch Belcher drifted 20 feet into the hill in an easterly direction and took out coal for several years. I. S. Salyer reports that the bed is about 4 feet

thick, with a thin slaty parting 10 inches from the roof and another 8 inches from the floor. This coal is about 340 feet below the lower Elkhorn, and may possibly be the Millard. Bear Fork is a left branch of Left Fork, 1 mile above its mouth.

Elkhorn coals.—At the head of Houselog Branch, near Basil Belcher's cabin, a prospect trench uncovered a coal bed supposed to be the Lower Elkhorn at an elevation of 1,612 feet or 200 feet above the cabin. The coal is reported to be 2 feet 10 inches thick, but can not be seen now on account of caving. Near the top of the ridge, at an elevation of 1,770 feet, directly back of the cabin, the Upper Elkhorn was located, but the trench had been allowed to cave. The bed is said to be 7 feet thick. The Upper Elkhorn at the head of Bear Fork is reported to be 9 feet thick, but this was not verified. The Lower Elkhorn on this fork is reported by I. S. Salyer, who lives at its mouth, to be 5 feet thick with a 6-inch parting in the lower portion.

At the head of Left Fork of Beaver Creek, in the run above the elbow in the road and close under the top of the ridge, Miles Potter has opened the Upper Elkhorn and timbered a drift about 20 feet deep. It shows a bed of coal 6 feet 9 inches thick, with only two thin partings not over an inch thick (31). This bed has an excellent appearance and would be worthy of attention except for the fact that it is so close to the top of the ridge as to have but little body. Even as it is, this bed might be worked in conjunction with the Lower Elkhorn if the latter should be mined on this creek. Several other openings have been made on the Elkhorn coals in the hills around Beaver Creek, but in most cases they were merely prospect trenches, and not being timbered they caved or fell in within a few months and the coal could not be seen.

GRASSY CREEK.

Geologic section.—At the mouth of Grassy Creek the Lee conglomerate rises 150 feet above the water on the west and nearly 1,000 feet on the east. This is because the Pine Mountain fault, but a few rods to the east of the creek, raises the Lee high in the air. A small coal bed in the Lee is said to be exposed at the mouth of the creek, but it was not discovered by the writer. Section 12, on Pl. III (p. 38), is compiled from notes on Trace Fork, and principally from Greasy Spur at the head of the fork. By tracing the rocks up the creek the conclusion was reached that the horizon of the Auxier coal is but little above the stream at the mouths of Trace and Cow forks. This being the case and the dip being gentle to the northwest, the position of a coal found near the head of the fork on Greasy Spur coincides closely with the position of the Lower Elkhorn.

Elswick coal.—Although no openings were seen on the Elswick coal between Elkhorn City and Grassy Creek, the horizon can be traced without difficulty just above the highway, which is for most of the distance near the top of the Lee conglomerate. The bloom of the Elswick coal shows in the road up Grassy Creek just north of Big Hollow.

Auxier coal.—The first opening on the Auxier coal that was seen in going up the creek is on Trace Fork, about one-third of a mile above Riley Cavin's place. Here a prospect shows 20 inches of coal (32) with a fossiliferous shale roof. This opening is 1,113 feet above tide. On the right side of Abes Fork just above Cavin's an opening at 1,153 feet, known as No. 1 of the Yellow Poplar Company, shows $2\frac{1}{2}$ feet of coal, and doubtless is the same bed. As the dip in the vicinity is northwest, it is possible that one of the two small beds found 1 mile farther up Abes Fork may be the Auxier. One is at the mouth of Locust Thicket, 1,140 feet above sea, and has 1 foot or more of coal, the whole thickness of the bed not being visible. The roof is blue fossiliferous clay. On the opposite side of Abes Fork and a few rods farther up, a crop in the creek bank shows a 19-inch coal bed (35), which is 20 feet higher than the one just described. It has a sandstone roof.

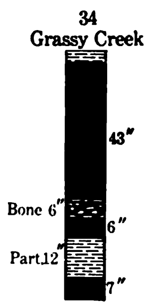


FIG. 7.—Yellow Poplar coal section.

The Yellow Poplar Company made three openings on a bed which lies about 100 feet above the Auxier, the three being 1,265 to 1,270 feet above sea. A clay parting is found near the bottom of each. No. 2 opening shows the bed 4 feet 2 inches thick with a 7-inch clay band. No. 3 is reported 5 feet thick with the same clay seam. This opening is said to have struck a fault 162 feet from the entry, which is quite possible, as this is close to the line of the Pine Mountain fault. No. 4 opening on the left of Old House Branch discovers the same bed over 6 feet thick (34) at the face of the drift, which is 1 foot more than at the mouth of the entry. A small fault having a northeast course at the face of the 15-foot drift displaces the upper bench a few inches, but does not disturb the bottom bench of coal.

Millard coal.—If the correlation of the Auxier is correct, then a coal found 200 feet above it on the left of Trace Fork should be the Millard. Tracing the horizon up the creek it seems to be the coal found at the southern end of Greasy Spur, which W. T. Griffith, a local surveyor, calls the Greasy Spur coal. Two openings on this coal made near water level $1\frac{1}{2}$ miles up Trace Fork show a bed 5 feet 8 inches to 6 feet 1 inch thick, with 3 partings (33). These are at an elevation of 1,220 feet. On Rattlesnake Hollow, 200 feet higher.

a 3-foot bed has been found. This has about the proper position to be the Bingham coal.

Lower Elkhorn coal.—So far as known only one opening has been made on the Lower Elkhorn coal in the valley of Grassy Creek. This is at the extreme head of the main branch of Trace Fork and at an elevation of 1,645 feet. It is on the east side of Greasy Spur and 400 feet lower than the gap leading to the head of Beaver Creek. The opening has been made since the writer left the field and is reported by Mr. Griffith to show a 4-foot 10-inch bed. The Upper Elkhorn should be found higher in the ridge, but can have only a small acreage on account of its position near the top of the hills.

MARROWBONE CREEK.

Geologic section.—The horizon of the Auxier coal is less than 100 feet above water level at the mouth of the creek while the great Flatwoods bed is 600 or 700 feet below the highest point in the area. There is then from the mouth of this creek to the divide at the head a geologic section nearly 2,000 feet thick. The rocks above the Upper Elkhorn coal are shown in the general section (fig. 3) and the lower rocks are partly represented in the Marrowbone and Henry Clay mine sections on the columnar section sheet (Pl. III, p. 38). It is sufficient to state that the Millard coal is found at the mouth of the creek at an elevation of 1,000 feet above tide or 270 feet above the river. The Bingham coal of workable thickness occurs 175 feet and the Lower Elkhorn 370 feet above the Millard. The Upper Elkhorn is 160 to 180 feet higher than the Lower Elkhorn and the Flatwoods bed is at least 500 feet above the former. The rocks between the coals are all shales and sandstones. The shales are in part argillaceous and in part arenaceous, while the sandstones vary from shaly to coarse and massive.

Auxier coal.—By tracing the rocks along the railroad from Moores Branch down the river to Marrowbone Creek, the coal on top of a massive sandstone and level with the roof of Marrowbone station seems to be equivalent to the Auxier. If so, the Auxier is an insignificant coal on this creek, for it is small in the outcrops along the railroad and passes below the level of the creek in a short distance.

Millard coal.—About 240 feet above the railroad, at the mouth of the Marrowbone, on the land of Alec Johnson, on the right of the creek, the Millard coal has been shown by an opening to be 2½ feet thick. On account of the dip to the west this coal is somewhat lower on Wolfpit Fork, where it has been opened (37) on John Coleman's place 1,000 feet up Left Fork. Dan Stewart keeps a small bank open across the run from his house in Laurel Hollow. He has

2½ feet (40) of solid coal between shales. One-half mile up Rockhouse Creek, on the north side and above the sawmill, where this coal has been opened on Henry Ratliff's land, the bed (46) has a bottom bench of 26 inches of solid coal overlain by 13 inches of shale, coal, and bone. One mile up Rockhouse Creek, where the Millard goes under water, it is exposed in the south stream bank for 75 feet and is a 2½-foot bed (47), the top 3 inches of which are bony. The roof is sandstone and the floor shale.

At the mine of the Marrowbone Coal and Coke Company, just above the mouth of Rockhouse Creek, there is an opening on the Millard at an elevation of 953 feet which shows 2 feet 4 inches of coal (41) with a shale roof. This opening is 370 feet below the Lower Elkhorn coal, which is mined directly above. It is known at the mine as the Auxier, but the writer feels certain it is the coal that has been traced from Coleman's at Regina to Huffman's at Millard, and not the coal which has been traced from the mouth of Marrowbone Creek to Elkhorn Creek.

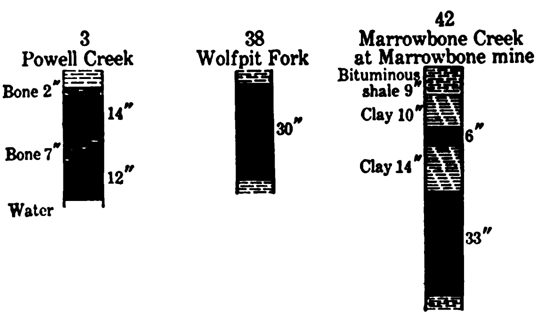


FIG. 8.—Bingham coal sections.

At the end of the railroad cut near the mouth of Johnson Fork there is a partly caved opening (45) in which the dip is 6° W. and which has 20 inches of clear coal in a 2 foot 9 inch bed. This bed, opened under the road below the mouth of Mill Creek, appears about 3 feet thick, but has too many partings to be of value. The sandstone roof is very irregular. These eight openings show an average of about 30 inches of workable coal in the Millard bed on Marrowbone Creek.

Bingham coal.—Two measurements were obtained of the Bingham coal on Marrowbone Creek. One is of the prospect made by the Marrowbone Coal and Coke Company at their mine, where the bloom was discovered 190 feet below the Lower Elkhorn in grading for the incline from the pit mouth to the tipple. The coal was faced close to the surface and the actual character of the bed under cover may not have been revealed. It showed 3 feet 3 inches of coal in two benches separated by 14 inches of clay (42). It is possible that there is some swelling here at the crop and that there may be thin partings in the lower bench which could not be distinguished in the weathered condition of the coal.

Another opening on this coal was seen at Alec Ratliff's, on Left Fork of Wolfpit Fork. It has a good appearance, being 2½ feet thick (38), and lies between shales.

Lower Elkhorn coal.—Besides the pits opened on the Lower Elkhorn coal for family use, many prospect trenches have been cut to prove its extent and character. The outcrop of the coal as shown on the map (Pl. I), which is from D'Invilliers's survey, was run in part by stadia. Many of the prospect trenches have been allowed to cave, so that the writer could not obtain measurements of the coal at so frequent intervals as did Mr. D'Invilliers, but nevertheless more sections of the coal were obtained than are deemed necessary for a thorough description of the bed in this part of the field. The character of the bed at 12 different places on the creek and its branches will be described.

On Wolfpit Fork there is an old pit near the head of the creek on the right above the bend, which shows the full section (36). The roof and floor are shale. The coal is 3 feet 4 inches thick, with 4 inches of bone on top, and without the partings or laminated coal that are found in much of this field.

At the head of the first hollow on the right of Marrowbone above Wolfpit and nearly opposite Bath Hollow there is an opening on Joe Ratliff's land from which coal is taken every winter. It has a shale roof and floor, but the section of the bed (39) differs in all its details from that just described. Here a 15-inch shale is overlain by 2 feet 9 inches of coal and underlain by 2 inches of bone and 9 inches of coal. Still there is no doubt that these two openings are on the same bed. At the head of Deadening Fork of Rockhouse Creek a pit (48) driven in about 15 feet on a dip 5° south shows practically the same character of bed as at the head of Wolfpit Fork.

The next opening on the Lower Elkhorn coal found in going up Marrowbone Creek is that at the Marrowbone mine, just above the mouth of Rockhouse Creek. At this point the bed is over 400 feet above the creek. Two drifts had been driven in 125 feet by September 1, 1906. These were run S. 30° E., and found the rocks dipping in that direction for 100 feet. At 125 feet from the crop the rocks begin to rise. The Lower Elkhorn at this mine has a shale roof and floor, 2 feet 8 inches of solid coal, and a top bench of 16 inches (43) of laminated coal. It is noticeable that the lower 4 inches of the laminated bench is rumpled or contorted, as if it had been rolled under a load. The fact that this 16-inch bench is not marketable, because it breaks down to slack and runs high in ash makes this bed less attractive for mining than it might otherwise be. The same trouble is found in all the mines that have attempted to market run-of-mine coal from this bed on Marrowbone Creek.

One-half mile below the head of Poorbottom Creek James Gibbs has run a drift in 75 feet on the left side on the Lower Elkhorn and

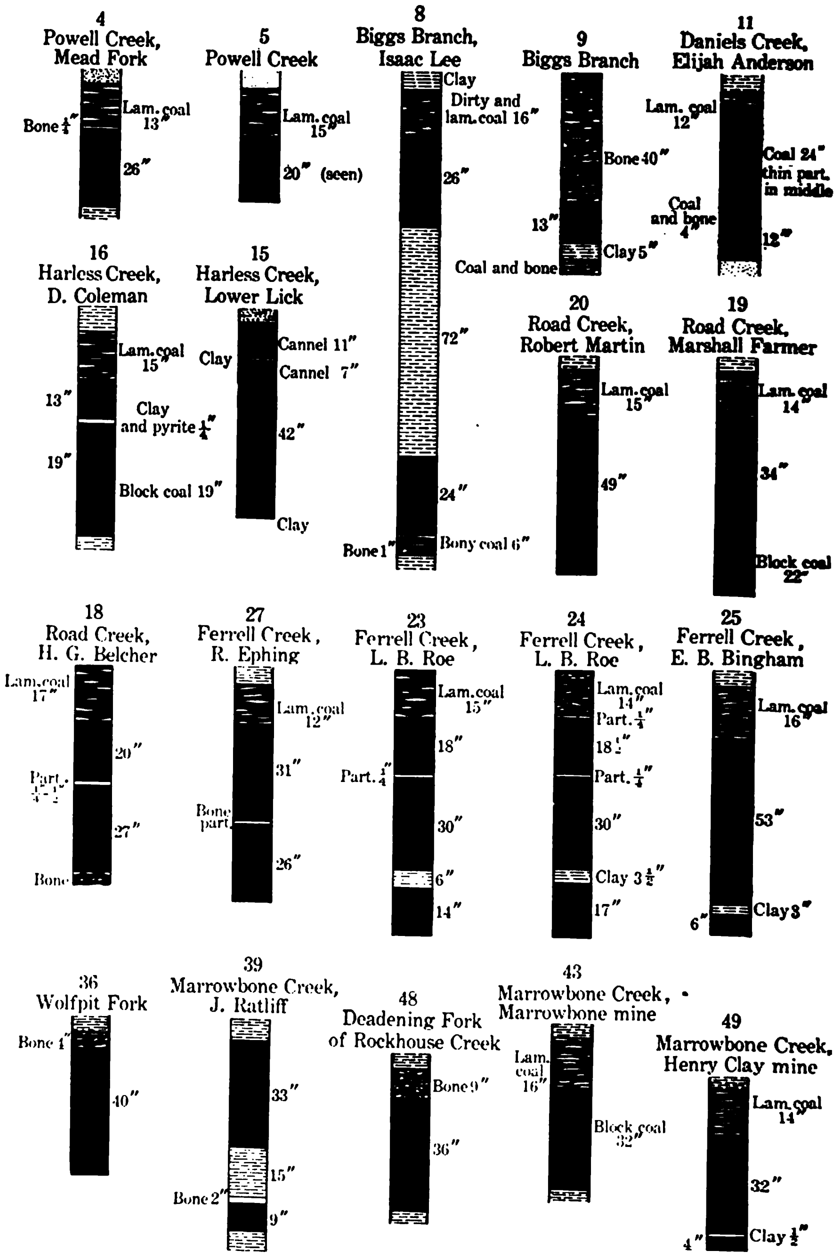


FIG. 9.—Lower Elkhorn coal sections.

found the bed about 3 feet 4 inches thick. At the head of Big Branch, on Levi Coleman's place, the same thickness is found, but the

upper 12 inches is a mixture of shale and coal. It shows 2 feet 6 inches of solid coal (51) with one parting. The floor is shale and the roof sandstone.

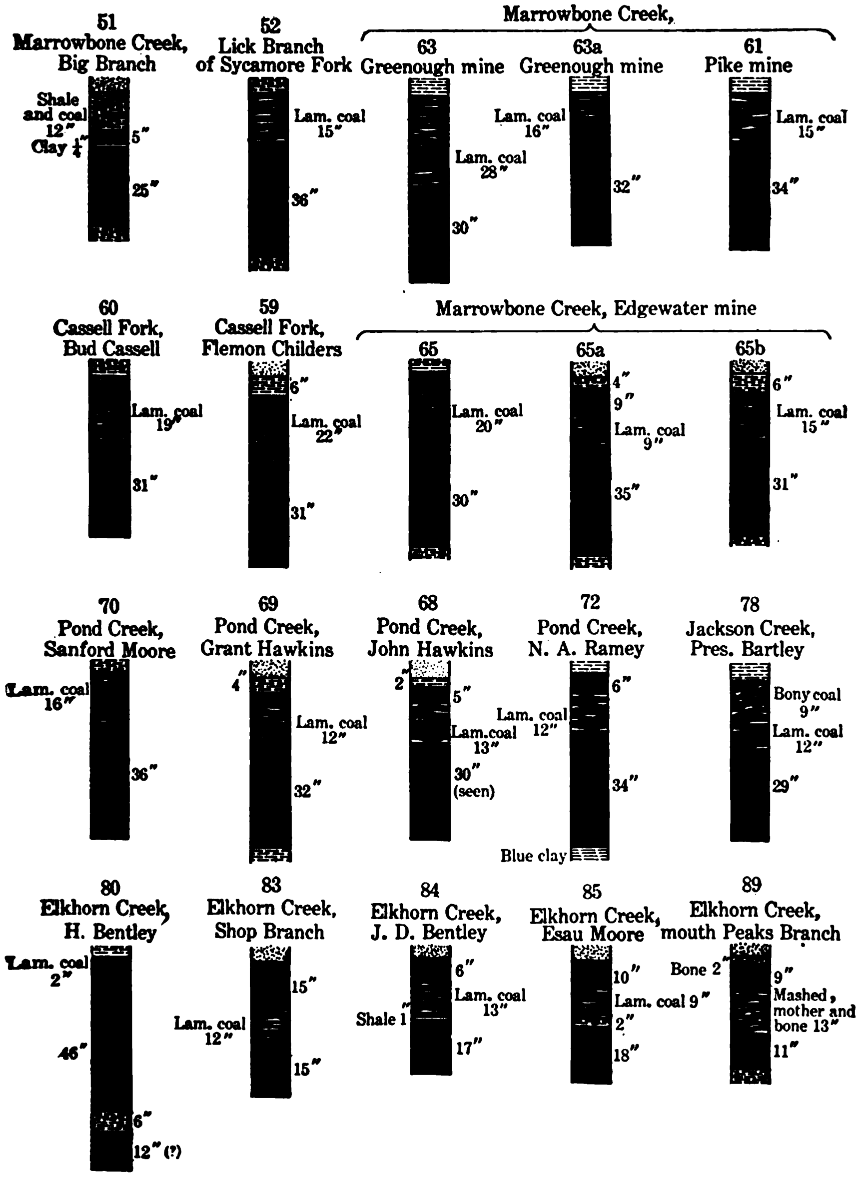


FIG. 10.—Lower Elkhorn coal sections.

The Henry Clay mine is between Poorbottom Creek and Big Branch. In September, 1906, an entry and parallel air course had been driven 550 feet. Two measured sections of the bed were ob-

tained, one near the outcrop (49) and the other at the face. In both places a one-fourth to one-half inch band of clay is found 4 inches above the floor, and the laminated coal is 14 inches thick. The difference between the two sections is the variation in the amount of coal between the clay band and the laminated coal. At the entry the main bench of coal is 2 feet 8 inches and at the face 2 feet 4 inches. The amount of marketable coal in the mine as developed at that time varied from 2 feet 8 inches to 3 feet. The roof is 3 feet of shale, which caves badly.

On Sycamore Fork one section was obtained (52) from an opening on the right of Lick Branch one-half mile above the mouth on the land of J. A. Mullins. Here there is a 60-foot drift showing 3 feet of solid coal and 15 inches of laminated coal. The roof and floor are shale. This is a very characteristic section of the Lower Elkhorn in much of this field.

The Greenough mine is on the left of Cassell Fork just above the mouth. Shale makes the roof and floor. The bed is composed of an upper bench of laminated coal and a lower bench of hard, block coal of fine appearance. At the mouth of the entry the laminated is 1 foot thick; 50 feet inside it has increased to 2 feet 4 inches (63), and at 300 feet from the outcrop it is 16 to 17 inches (63a). The lower bench or block coal at the same points is 2 feet 10 inches, 2 feet 6 inches, and 2 feet 8 inches to 3 feet. The main heading was full of water in September, 1906, and the face 600 feet from the entry was said to show only 6 inches of coal. This is the only instance known to the writer in which the Lower Elkhorn coal falls below 2 feet in thickness, but it suggests the possibility of other considerable variations being found as development progresses. Unless the bed maintains a fairly constant thickness and some use can be found for the laminated coal, the Lower Elkhorn does not promise to be a good mining proposition in this part of the field.

At the Pike mine, on Cassell Fork 1 mile above Hellier, the laminated coal varies from 2 to 22 inches and the solid coal from 2 feet [illegible] inches to 3 feet 9 inches. The following measurements were obtained in the lower mine:

Sections of Lower Elkhorn coal at Pike mine.

Location.	Laminated.		Solid.		Total.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Face of first left entry	1	3	2	10	4	1
Second left heading	1	8	2	7	4	3
Face second left heading	1	5	2	8	4	1
Room 3, second left heading	1	7	3	2	4	9
Room 2, second left heading	1	3	2	8	3	11
Main heading	1	9	2	8	4	5
Main heading		2	2	8	2	10
Main heading		5	3	9	4	2
Face of main heading	1	10	2	8	4	6
Face of air course	1	6	2	9	4	3
Face first right off air course	1	3	3	0	4	3

In the main heading where for a few rods the laminated coal is ·ery thin, a soft clay is found between it and the overlying shale, nd there are abundant evidences of movement. The block coal .t this point is undisturbed. The mine shows an average of 34 nches (61) of marketable coal. If means could be devised for relucing the amount of ash in the laminated coal, or of using this ench to advantage, the worth of the bed would be greatly increased.

The laminated coal of the Lower Elkhorn bed was sampled at hree different points in the Pike mine and mixed to get a fair verage. Samples of the solid coal and of the whole bed were taken or comparison, and the analyses are given on page 72. These nalyses show only 4.08 per cent of ash in the solid coal, but 22.37 per cent of ash in the upper bench or laminated coal makes the proportion of ash in the whole bed objectionably high. The companies operating on Marrowbone Creek have found that their customers will not accept run-of-mine coal from this bed, and they are obliged o throw the laminated on the waste dump.

The writer's sample of the whole bed is higher in ash than sameles taken by others, which are said to represent the entire thickess of the bed. He is confident that the sample taken in the Pike ine is representative of the laminated portion of the Lower Elkrn coal, and this statement is supported by the following analyses. the writer's request Mr. Lowry Lewis, manager of the Pike mine, it 50 pounds of laminated coal in chunks representing the different ases of its occurrence. From these the writer selected three sames which may be described as follows:

Sample 1. Dull, bony coal with numerous paper-thin lamellæ of bright coal. aks in flat slabs.

Sample 2. Bony coal, about two-thirds dull and one-third bright, glistening aellæ. Breaks in flat slabs.

Sample 3. Mixed dull and bright coal, mashed, contorted, and showing many k faces. Slacks very readily.

Analyses of these samples made in the chemical laboratory of the rvey by George Steiger show the following ash content: Sample . 1, 35.22 per cent ash; No. 2, 18.81 per cent ash; No. 3, 10.26 per nt ash.

Whether the percentage of ash could be greatly reduced by washg the laminated coal should be determined by testing several tons a coal washery.

Further evidence of the high content of ash in the laminated porion of the Lower Elkhorn coal bed is shown by the following nalyses from samples taken by independent investigators:

Analyses of laminated bench of Lower Elkhorn coal.

	Marrow-bone mine.[a]	Edgewater mine.[a]	Peters Creek.[b]
Moisture	2.70	1.52	----------
Volatile matter	28.24	28.46	31.00
Fixed carbon	42.50	49.18	52.75
Ash	26.56	20.84	16.25

[a] Analysts, Froehling and Robertson. [b] Analyst, J. O. Mathewson.

The sample which represents the Marrowbone mine was taken by S. M. Buck, of Bramwell, W. Va., from a single lump of laminated coal, and does not profess to be an average. The laminated coal in this mine is 15 inches thick and overlain by 2 inches of solid coal. The sample from the Edgewater mine was taken by Mr. Buck from a point where the bed from top to bottom measures: Solid coal 9 inches, laminated coal 8 inches, solid coal 2 feet 6 inches. J. W. Paul, mine inspector of West Virginia, sampled the laminated coal in the Lower Elkhorn bed at Solomon Layne's, on right fork of Peters Creek, a few miles north of the field here described. The laminated coal is 7 inches thick and is overlain by 17 inches of solid coal. These 4 analyses of the laminated, ranging from 16.25 per cent to 26.56 per cent, give an average of 21.50 per cent ash. Two samples of the Lower Elkhorn taken by the writer, from which the laminated was excluded, give an average of 3.08 per cent ash for the solid coal. Considering the proportion of laminated to solid coal, the average amount of ash in the whole bed is on this basis about 10 per cent. An average of 14 analyses by A. S. McCreath and H. J. Williams of the Lower Elkhorn coal on Marrowbone Creek, including the whole bed, gives 8.15 per cent ash. The maximum and minimum amounts of ash in these 14 samples are 13.48 and 1.98 per cent.

The fact that the laminated is overlain in many places by undisturbed solid coal shows that the ash can not be due to a mixture of shale or clay pulled down from the roof during the movement which produced the lamination. The lamination seems to have developed in a portion of the bed which was originally high in ash, and the combination of the coal and its impurity is such that washing would probably not greatly reduce the amount of ash.

On Marrowbone Creek the laminated bench forms so large a portion of the bed that, as long as it has to be thrown out, the Lower Elkhorn is not attractive for mining. Between Russell and Levisa forks the usual 15 inches of laminated coal is present in the top of the bed, but the whole thickness is so much greater that the loss of the laminated is much less important.

The laminated is not a shipping coal, because it breaks down to slack, but probably could be used successfully at the mines for pro-

ducer gas, either for heating or for power. Low-grade coals, high in volatile matter, can be used economically in producer-gas plants.

In an opening at Bud Cassell's, farther up Cassell Fork, the lower bench is normal (60), but the laminated coal has increased in thickness to 19 inches. At Flemon Childers's, in a bank where coal has been taken for two or three years, the block coal is 3 feet 1 inch, and the top bench, bony and laminated, only 8 inches. Still farther up the fork, where the coal approaches water level, the (59) block coal is 2 feet 7 inches and the laminated 1 foot 10 inches.

In the Edgewater mine, at the head of Marrowbone Creek, the Lower Elkhorn maintains a fairly constant thickness. Sections were measured at the mouth (65), 230 feet in (65 a), and at the face of the main entry 370 feet from the crop (65 b). These show a lower bench of 2 feet 6 inches to 2 feet 11 inches, and an upper bench from 15 to 20 inches thick. In one section (65 c) 9 inches of solid coal overlies an equal thickness of laminated.

Upper Elkhorn coal.—The first opening on the upper Elkhorn coal above the mouth of the creek is that at the Marrowbone mine near the mouth of Rockhouse Creek. The Marrowbone Coal and Coke Compay has done development work on both of the Elkhorn beds, one mine being directly above the other and both served by the same incline. On the upper coal an entry (44), driven 125 feet S. 30° E., shows a section of the bed which is different from any other found in the vicinity. At the mouth of the entry it is 3 feet 10 inches thick, but includes a 17-inch clay parting, the bottom of which is 9 inches above the floor. According to R. C. Peacock, manager of the mine, this clay, which contains small streaks of coal, is 12 inches thick at the face of the drift and is two-thirds coal.

When this creek was visited in September, 1906, a drift on the Upper Elkhorn coal had been driven 70 feet northwest at the Henry Clay mine and showed a bed 4 feet 5 inches thick (50). At Cynthia Gibson's, on Lick Branch of Sycamore, a 70-foot drift shows this coal 5 feet thick (53), and on Henry Bowen's land, at the head of Sycamore (54), the bed is 3 feet 6 inches thick.

The first exposure up Cassell Fork is at the Greenough mine, where there is a bed of solid coal (64) nearly 4 feet thick. A sample of the whole bed at this mine was taken by the writer and the resulting analysis will be found on page 72.

At the Pike mine, a mile up the fork (62) the bed is less than 3 feet thick and the upper 5 inches is bony or mashed. Farther up Cassell Fork there are several prospects exposing the Upper Elkhorn. Among these are a pit on Flemon Childers's land (58) and a trench on the Musgrave place which show the bed from 3 feet 3 inches to 3 feet 9 inches thick, the upper 8 inches being bony or laminated.

At the Edgewater mine, on the head of Marrowbone Creek, the Upper Elkhorn coal is nearly 4 feet thick. The main entry shows 2 feet 8 inches of solid coal at the mouth and 2 feet 10½ inches at the face (66), the rest being bony or laminated.

An average of 9 sections measured on this creek gives a fraction over 3 feet for the thickness of the solid or marketable coal.

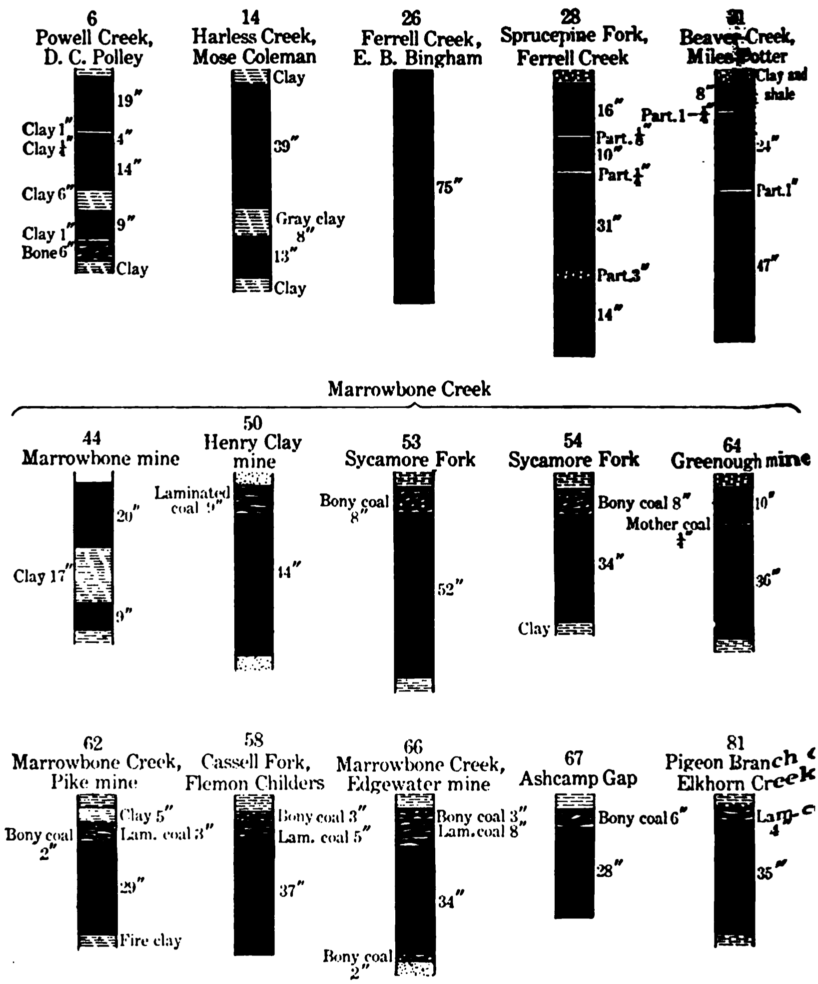


FIG. 11.—Upper Elkhorn coal sections.

Flatwoods coal.—An approximation of the area underlain by tl Flatwoods coal is shown on the accompanying map (Pl. I). Tl stratigraphic position is 500 to 550 feet above the Upper Elkhor It has been prospected but little. A measurement of the bed wa made at the head of Cassell Fork in a trench cut for the Big Sand Company and the total thickness (55) found to be 18 feet 9 inches

; the upper 6½ feet is workable coal, and a sample was taken .lysis. The lower 12 feet of the bed is too much broken up by ırtings to be of value. Two other openings in this same · (56, 57), according to measurements by E. V. d'Invilliers, 4 feet 2 inches and 16 feet 7 inches, respectively, but much of is worthless.

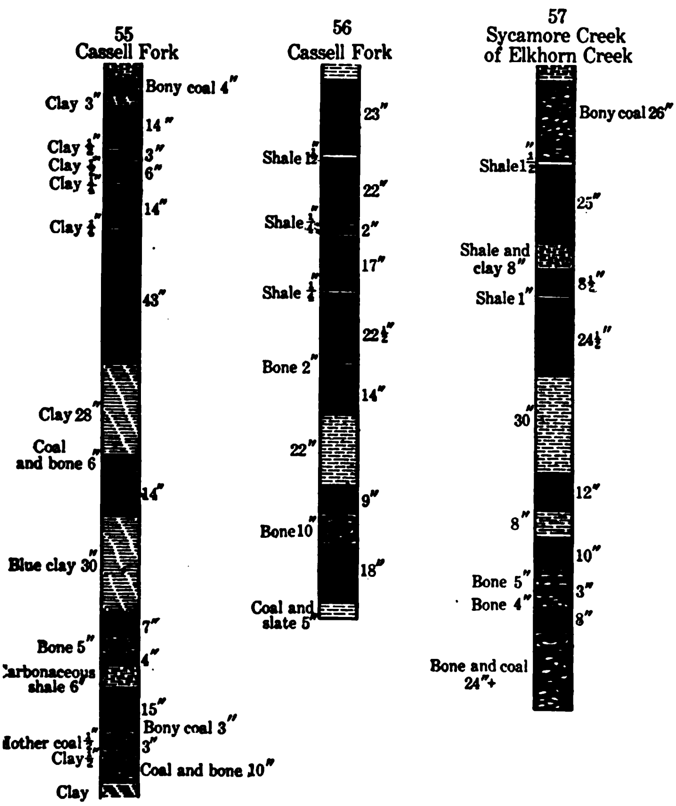


FIG. 12.—Flatwoods coal sections.

he Flatwoods table-land 500 feet above this coal another bed rted[a] to have been opened at the head of the right fork of ›re Fork of Elkhorn Creek. It was not seen by the writer, s reported to be 4 feet thick with only one thin shale parting.

POND AND JESSE CREEKS.

›gic section.—The geologic section in these creeks begins about t below the Auxier coal and extends a short distance above the Elkhorn coal. The ridge between the two creeks is too low to

[a] Iall, A. R., The coals of Big Sandy Valley: Kentucky Geol. Survey, Bull. No. 4, 116.

catch the Upper Elkhorn, but it is present around the head of Pond Creek.

Small coals.—So far as learned the Auxier was not open at any place on Pond or Jesse creeks and no information could be obtained as to its thickness. A coal occurring at a higher horizon was seen in the bank of Pond Creek above an old mill, which is just below Camp Branch, at a point about 200 feet higher than Russell Fork. This is near the horizon of the Millard and is a 3-foot bed (71), with clay partings. Eighteen inches of solid coal was seen at the bottom, resting on sandstone. Between Camp Branch and Laurel Branch, opposite Sanford Moore's house, a facing shows two 6-inch bands of coal, separated by 17 inches of shale. There may be other small, worthless beds in the section exposed along this creek, but their presence was not discovered.

Lower Elkhorn coal.—This coal was opened by Sanford Moore on the left of Pond Creek just below the mouth of Laurel Branch in April, 1906. It is marked by a chute, which brings the coal down to a bin at creek level. The bank furnishes fuel for the dinky locomotive of the Clinch Valley Lumber Company, which is operating on this creek. Normal conditions for this region are found here, the bed having a total thickness of 4 feet 4 inches (70), the upper 16 inches being laminated. Shale forms the roof. An analysis of a sample from the bed at this point, including both laminated and solid coal, is given on page 72.

William Ramey reports that the coal was once opened in the head of the hollow back of his house, and showed a 4-foot 4-inch bed, with 2 inches of slate between the solid coal and the laminated. Mr. Ramey lives at the mouth of the branch on the right, just above Laurel Fork. In a hollow on the right, one-half mile above Ramey's, a bank has been driven about 80 feet N. 75° E., and coal is brought out in a small tram car to a chute for loading on wagons. The westward dip of the rocks makes the drainage good. The section here is the same as at Moore's, 3 feet of solid coal with a 16-inch bench of laminated on top.

An entry on the right branch of Laurel Fork has been driven 3[illegible] feet in a southwest direction, according to Sanford Moore, but the water flows in and the pit is now full. The bed is reported to be [illegible] feet 5 inches thick, with 12 inches of laminated separated from the solid coal by soft "mother coal."

Back of Grant Hawkins's house at the forks at the head of Pond Creek a drift 75 feet long has been run into the hill S. 25° E. on a dip of N. 55° W. The bed is 4 feet thick (69), the lower bench having one or two one-fourth inch partings that are not persistent. At John Hawkins's farther up the creek, a 70-foot drift on the same bed

(68) shows the laminated coal 1 inch thicker and the solid 2 inches thinner than at Grant Hawkins's. The floor in both places is shale, but at the first-mentioned locality only 2 inches of shale lie between the coal and sandstone roof.

The Lower Elkhorn coal has been prospected by N. A. Ramey at the left head of Camp Branch of Pond Creek. His pit shows (72) a shale roof, a bed almost the duplicate of Hawkins's, and a blue-clay floor.

In Jesse Creek the Lower Elkhorn has been opened at the head of a hollow off the left branch. The entry which has been driven 60 feet shows 3 feet of shale between the coal and overlying sandstone, and a bed at least 3 feet 8 inches thick, the upper 14 inches of which is laminated coal. The bottom was not seen. Frank Owens, who lives at the head of this creek, reports an opening on the right side of the right fork, that was driven west 75 feet on a coal bed dipping in the same direction. The roof is weak shale, and the bed 5 feet thick, the upper half of it being worthless. Coal opened back of Owens's house, about 250 feet below the Lower Elkhorn. is said to be 2 feet thick.

Upper Elkhorn coal.—A bloom of the Upper Elkhorn coal was seen at the head of Pond Creek, above John Hawkins's bank (68). The coal is reported to be 4 feet thick, the lower part peacock coal and the upper a good blacksmith coal. About 100 feet higher in the hill a hole shows another bed 42 inches thick, with a sandstone roof and 5 inches of clay 1 inch from the top. Grant Hawkins is authority for the statement that there is a 1-foot coal 20 feet above this and a 3-foot coal still higher. These were found in plowing and are not now exposed. Sanford Moore reports a bed of solid coal 5 feet 2 inches thick at the head of Laurel Fork, 340 feet above the Lower Elkhorn and too high to be the Upper Elkhorn. An entry was driven in on it 4 feet up the rise, when digging stopped. The pit has caved so that the report could not be verified.

LITTLE CREEK AND MOORES BRANCH.

Geologic section.—A section measured in the river bluff between these two branches and giving the sequence of the rocks from the railroad to the top of the intermediate ridge will be found on Pl. III (sec. 10). Unfortunately none of the coals above the Elswick were seen in climbing the hill, and the positions indicated in the section are only suggestions of their probable location.

Elswick coal.—This coal rises above the river at the mouth of Little Creek and is exposed just below Moores Branch in the rock cut along the railroad a few feet above the track. The cut shows a shale roof, 3 feet to 3 feet 4 inches of coal (75), and a sandy shale floor 2

feet thick resting on a massive gray micaceous sandstone. There is a small pyrite stringer near the bottom of the bed. The Elswick has been opened on Moores Branch, but is now caved.

Auxier coal.—On Little Creek, on the north hillside back of C. C. Maynor's house, there is a 30-foot drift running northwest down the dip of the Auxier coal, which is 3 feet 8 inches thick and has two partings near the bottom (74). A prospect on the point between the forks of the creek, at an elevation of 946 feet, is caved, so that the coal can not be seen. Calvin Ramey has an opening on the Auxier in the hollow one-half mile below Little Creek. It is 150 feet above the railroad, on the left fork of the hollow, one-fourth mile from his house (73). He opened it in the winter of 1905 and drifted S. 70° W. a few feet, then turned S. 20° W. At the time it was visited only 2 feet 3 inches of coal could be seen, but Mr. Ramey reported a thin parting and 7 inches of coal below the floor of his bank. This was confirmed by a prospect in the same hollow, a few rods away, where the thickness of the bed is 3 feet 1 inch with a 2-inch parting 7 inches from the floor.

The outcrop of the Auxier goes below water level about three-quarters of a mile up Moores Branch. It has been prospected in two places near the stream, but the only measurement made on the branch was obtained in the first little sag on the left 200 yards upstream from the railroad and 200 feet above the branch. This is the thickest section of the Auxier seen in the field, being 4 feet 6 inches (76) with a 2-inch clay parting near the bottom. The usual shale roof and sandstone floor were found here.

ELKHORN CREEK.

Geologic section.—A section (Pl. III, sec. 11) measured in the 800-foot bluff opposite Elkhorn City at the mouth of Elkhorn Creek indicates the sequence of rocks exposed in this valley. The top of the Lee conglomerate is a few feet above water at the creek mouth, and the Lower Elkhorn coal is near the top of the ridge. A heavy sandstone 500 feet above the river is correlated with that which makes a conspicuous ledge at Ashcamp, and a 12- to 15-inch bed of coal found near the mouth of Jackson Branch is thought to be near the horizon of the Millard coal. At Joes Branch and in the vicinity of Pound Gap the Upper Elkhorn is barely 100 feet above the creek.

Elswick coal.—The eastward rise of the rocks puts the Elswick coal 870 feet above tide at Elkhorn City. Openings near the mouth of Elkhorn Creek have caved in, but the Elswick coal is seen on the left 80 feet above the creek at the ford a half mile from Elkhorn City. The old coal bank is full of water, but at least 2 feet of coal is visible. At the other end of the same field, opposite the mouth of

Cane Branch, close to Alexander Adkins's house, there is an entry 20 feet deep. It has a sandstone floor and a good shale roof. The bed (77) is 2 feet 9 inches thick, with a half-inch band of sandstone close to the top. On the right side of the creek above the mouth of Cane Branch a bank is kept open to supply a small local trade and shows 2 feet 6 inches of coal. Roof and floor are the same as at Adkins's, and the dip is to the west. This dip makes drainage on the right side of the creek difficult. The Elswick coal bed goes below creek level near the mouth of Pond Branch on the land of Alec Roberts.

Auxier coal.—Although the outcrop was traced up the west side of Elkhorn Creek for more than 2 miles, no measurements were obtained on the Auxier bed. In the bluff opposite the store at Elkhorn City coal was found about 275 feet above the Lee conglomerate, or 300 feet above the river, on top of a 30-foot massive sandstone and overlain by shale. This seems to be at the horizon of the Auxier, but the section is so different from any seen elsewhere that it is questioned and was not considered in determining the average thickness of the Auxier bed. At this place there are two benches of coal, the upper 18 inches and the lower 12 inches thick, separated by 6 feet of shale. The Auxier falls below the creek in the bend below the mouth of Kettlecamp Branch.

Lower Elkhorn coal.—Few openings have been made on the Lower Elkhorn coal bed on the lower part of the creek. The first observed is in Jackson Branch, where William and Caleb Wood have a pit on the left of the stream a little over a mile above the mouth. This pit shows a 4-foot 2-inch bed, the upper 15 inches being laminated. In a hollow on the right, one-half mile below Wood's, Pres. Bartley opened the same bed (78) in the winter of 1905, one-fourth mile up the hollow and 325 feet above Jackson Branch. The bed has the same thickness as at Wood's, but only 2 feet 5 inches of it is solid block coal.

On Ashcamp Branch, back of G. W. Bartley's store, a bank opened on the Lower Elkhorn reveals 10 inches of solid coal underlain by 9 inches of laminated coal and a bottom bench at least 2 feet 6 inches thick. The drift is driven about 30 feet S. 20° E. on a northward dip.

In the head of a hollow on the right of Sycamore Creek there is an opening in which 30 inches of solid coal was seen, with an upper bench of 15 inches laminated and 5 inches bony coal. The bed is said to be 5 feet thick in the face of the drift, which is 42 feet long. On the west side of the same hollow a drift was once driven 35 feet on the coal by Joel Ratliff, who says he found 8 feet of solid coal at the base and nearly 10 feet of laminated coal above. The drift caved, burying tools, car, etc., and has never been reopened.

An opening on Harry Bentley's place, below the mouth of Pigeon Branch, shows a 4-foot bed, only the upper 2 inches being laminated (80).

On the right side of Big Branch an opening on A. W. Childers's property shows the Lower Elkhorn, which is there (82) composed of 30 inches laminated coal and only 13 inches solid coal. This is hardly representative of the bed, however, for it seems to be close to a local fault which may have affected the proportions of laminated and block coal. On Shop Branch a pit opened by Don Ratliff reveals this bed 3 feet 6 inches thick with 1 foot of laminated coal (83) in the middle, and on the head of Shelby Creek at Blackhead Vanover's a 40-foot drift shows 10 inches of solid coal at top and 15 inches at the bottom, but with 20 inches of laminated coal in the midst of the bed. This coal shows a bloom in the road just below Shelby Gap.

Along the road one-fourth mile above Shelby Gap, where the creek has cut a rock cliff, there is exposed a 21-inch bed of coal and bone which can be traced to Marshall Branch. This bed lies over 40 feet below the Lower Elkhorn coal. In the hollow back of J. D. Bentley's house the Lower Elkhorn has been developed by an entry driven N. 70° E. 25 feet under a sandstone roof. The bed is 3 feet thick and has a 1-inch shale band between the solid and laminated coal (84). At Esau Moore's, a little farther up the creek, the small bed mentioned above is at water level 18 inches thick, and a 15-inch bed is about 20 feet above it. In the hollow opposite Moore's house, 50 feet above the creek, there is a pit on the Lower Elkhorn which shows much the same characters (85) as are seen at Bentley's. In the bed of Marshall Branch, below the forks, at William Isom's, the Lower Elkhorn appears again with the same sandstone roof, 7 inches of solid coal and 7 inches of laminated, separated from the 18-inch block coal by 2 inches of shale. At the forks, a few rods farther up the branch, a pit discloses a coal bed 2 feet 8 inches thick, which can be but little above the Lower Elkhorn.

Just above water level in the bank of Elkhorn Creek at Alex Isom's, below Peaks Branch, an opening on the Lower Elkhorn coal shows the bed to be nearly 3 feet thick, but with over a foot of laminated and bony coal in the middle (89).

Upper Elkhorn coal.—This coal is so high in the hills along the lower part of the creek that little prospecting has been done on it below Shelby Gap. A pit at Ashcamp Gap, 1,577 feet above tide, reveals a 2-foot 10-inch bed (67), the upper 6 inches of which is bony. On the longest fork of Pigeon Branch a 100-foot drift made by L. J. Vanover shows 4 inches laminated and 35 inches solid coal at the face (81).

On Marshall Branch the Upper Elkhorn begins to assume the proportions that have become famous in this region. At the head

he right fork William Johnson takes coal from a prospect pit) at creek level, in which there is a top bench of coal 31 inches k and a lower one at least 20 inches thick. The whole bed was exposed, so the floor could not be seen, but the roof is fossil- ous shale. At the head of the left fork of Marshall Branch e are two openings in which the bed is 8 feet thick. At Caleb

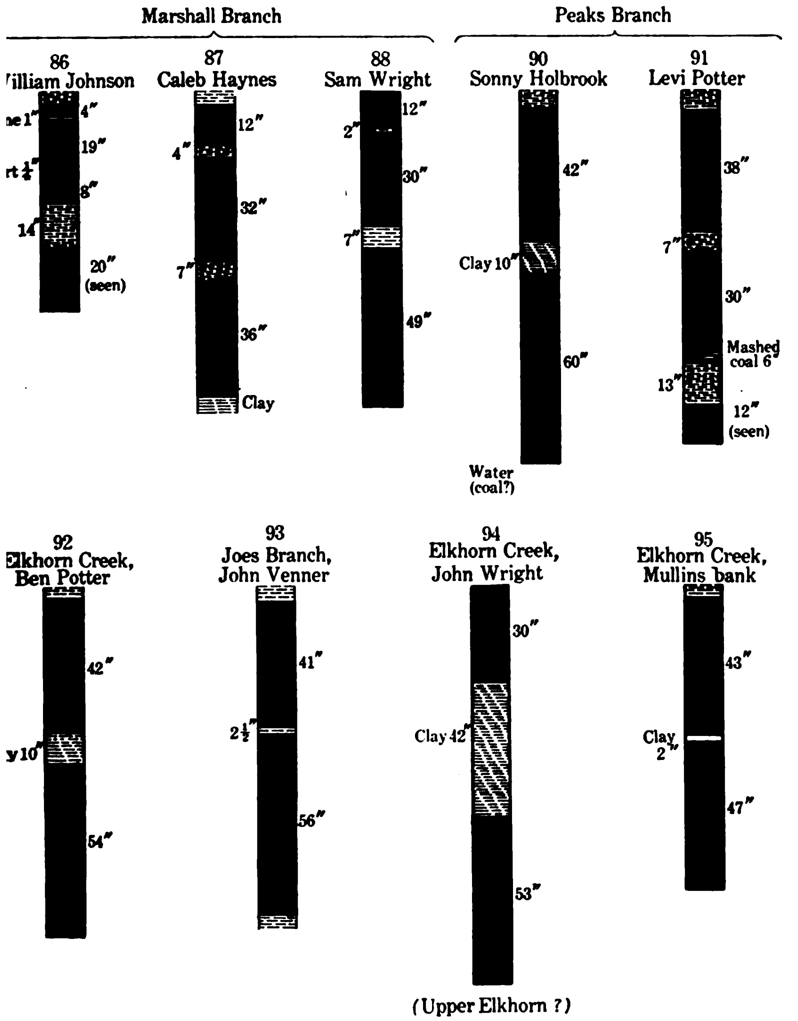


FIG. 13.—Upper Elkhorn coal sections.

ynes's place (87) there are two partings from 4 to 8 inches thick, le at Sam Wright's, where a trench cut in the hillside (88) shows d 8 feet 9 inches thick, only 9 inches in all is parting.

n Peaks Branch, a quarter of a mile from the mouth and in the back of a cabin, there is a pit known as the Sonny Holbrook

opening, which shows the bed at least 10 feet thick (90) with only one 10-inch parting. The entire bed was not measured because of water in the pit. On the right fork of Peaks Branch, opposite Levi Potter's house, a trench shows the bed (91) to be at least 9 feet thick and the bottom was not seen. Twenty inches of shale in two partings are included.

On Bens Branch near Ben Potter's house, about 100 feet above Elkhorn Creek, this coal is finely shown in a drift 20 feet long. The bed is 8 feet 10 inches thick and has only one parting, which is near the middle (92). The analysis of this coal from the writer's sample given on page 72 shows that it is of very high grade.

The bed is equally good on Joes Branch, where the Blevens opening, on John Venner's land (93), shows a section of 8 feet 3½ inches with only 2½ inches of parting instead of 10.

At the mouth of Little Elkhorn, less than 40 feet above the creek and close to the ford, a prospect on John Wright's land shows a bed which was not recognized. Whether it is the Upper Elkhorn or not is an unsettled question. The dips in the vicinity suggest that it is a lower coal than the one seen at Mullins's near the head of the creek. This bed at Wright's is nearly 9 feet thick, but it carries 42 inches of clay (94) in the middle.

At the main head of Elkhorn Creek, the fork flowing from the north toward Pound Gap, there is an opening commonly known as the Mullins bank (95), which shows the Upper Elkhorn 7 feet 7 inches thick separated near the middle into two benches by 3 inches of clay. The lowest bench has several 2-inch bands of lusterless splint coal. An analysis of a single chip of this dull coal showed 6 per cent ash. A sample of the splint coal in the lower bench of the Upper Elkhorn taken by J. J. Hillsman, presumably at the Mullins opening, had, according to J. W. Fox, the following composition:

Analysis of Upper Elkhorn splint coal.

[Otto Wuth, analyst.]

	Per cent.
Moisture	0.96
Volatile matter	34.56
Fixed carbon	62.389
Ash	1.60
Sulphur	.519
Phosphorus	.002

This is surprisingly low in ash, for the splint coals in the southern part of West Virginia average between 3 and 4 per cent ash. This sample represents 14 inches of splint coal found 23 inches above the floor. The entry to the Mullins bank (Pl. IV, *A*) has been driven about 50 feet S. 15° E.

A. MULLINS OPENING ON UPPER ELKHORN COAL, HEAD OF ELKHORN CREEK.

UPPER ELKHORN COAL ON WRIGHTS FORK OF BOONE FORK OF KENTUCKY RIVER.

B from photo loaned by Jno. C. C. Mayo.

Coal was taken from the Mullins bank for testing the coking quali-
:ies of the Upper Elkhorn in beehive ovens built by the Northern
Coal and Coke Company on John Wright's farm. The character of
:he coke is described in a later chapter. An analysis of the coal in
:he Mullins bank, given repeatedly in the reports of the Kentucky
Geological Survey and of the inspector of mines, will be found on
page 73.

Reports by A. R. Crandall, of the Kentucky Geological Survey; Neil Robinson, of Charleston, W. Va.; H. Hardaway, of Georgel, Va.; Arthur M. Miller, of Lexington, Ky., and others, all agree that :he Upper Elkhorn maintains the same thickness and characteristics as here described throughout a large area around the heads of Boone Fork of Kentucky River and of Shelby Creek (Pl. IV, *B*). This average thickness of 8 feet is not confined by any means to the head of Elkhorn Creek. The thickness of the bed, its extent, and its steaming and coking qualities all point to the conclusion that it is the best mining bed in the field here discussed. It is not at present within easy reach of a railroad. Mr. Crandall calls this the Lower rather than the Upper Elkhorn coal.

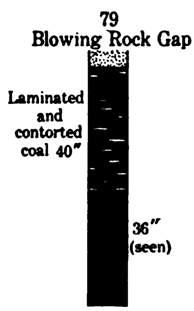


FIG 14.—Coal on Blowing Rock Gap road.

Coals on the flank of Pine Mountain.—Coal has een found in several places on the flank of Pine Mountain, east of Elkhorn Creek, but because of the teep dip it is not known just what beds are exosed here. A coal reported to be 9 feet 6 inches ick, on William Potter's land, between Joes ranch and Pound Gap, has a section similar to at of the Upper Elkhorn on the other side of the eek. Although a bed over 8 feet thick was seen, the bottom of the al was not reached, and it is possible that the reported thickness is rrect. The bed reported by the Kentucky Geological Survey, 1 mile Pigeonroost Creek, at water level, is said to be 10 feet of clean, lid coal. An analysis of this coal given in the table (p. 73) shows at it is of high grade.

Several other openings were reported on the mountain side, but ey are caved so that the coal can not be measured. A coal has been und in a hollow on the north side of the road from Ashcamp to owing Rock Gap near George Bartley's house. An opening made n years ago is so caved now that only a portion of the bed, reported om 9 to 11 feet thick, is visible. The writer saw under a massive ndstone 40 inches of mashed and contorted coal which rested on 3 et of solid coal (79). It was evident that only a portion of the ock coal was exposed. The statement of the neighbors is that a tall nan could stand under the slaty or laminated coal and not rub his

hat. This being so, the bed is at least 9 feet thick at this point, it is possible that this may be a pocket, and that any coal on mountain side close to the fault is badly crushed and possibly br by small faults. An analysis of this coal by the Kentucky Geolo Survey is given on page 73. It hardly seems possible that the l nated coal or the whole thickness of the bed was included in the ple from which this analysis was made, for it shows only 2.16 cent ash.

SUMMARY.

It will be seen from the foregoing description of the field th contains six coals of workable thickness. Two or three other have a problematic value. The following table shows the rang thickness of the workable beds:

Summary of coal beds.

Name of coal bed.	Maximum.		Minimum.		Average.		Num sec
	Ft.	in.	Ft.	in.	Ft.	in.	
Elswick	3	10	2	6	3	1	
Auxier	4	11	1	8	3	1	
Millard	4	4	1	6	2	5	
Bingham	4	5	2	6	3	1	
Lower Elkhorn	6	11	2	9	4	3	
Upper Elkhorn	9	4	2	10	5	8	

It should be borne in mind that this table is based on total tl ness of bed, and does not represent the amount of marketable contained in each bed, nor indicate which are and which are not mining beds. For instance, although 5 sections of the Elswick give an average of 3 feet 1 inch for the whole, the average am of workable coal in the sections is only 2 feet 7 inches.

The Auxier coal is shown to be about 3 feet thick, and as it usu has but one parting it can be counted on to yield at least 2½ fe coal in part of the field. Present conditions do not as yet den the development of beds of this size, but they constitute a re which may at some future day, when the thicker beds have beeı hausted, yield a large tonnage of good bituminous coal.

It appears from the above table that the Millard coal bed ra from 1 foot 6 inches to 4 feet 4 inches thick, averaging 2 feet 5 in Lest this be misleading, it should be stated that the thickest kr occurrence of the bed is on Jimmie Creek (17), where it is unw able because it contains too much shale and pyrite. There is onl inches of solid coal in the thinnest section, and this is too litt mine. The Millard is a mining bed, therefore, in only a portio its extent, and several decades will pass before it becomes neces to touch a bed of this character in the great coal field of ea Kentucky.

The Bingham coal was seen at so few points that little is known of its extent or character.

Of the Lower Elkhorn coal it should be noted that the average thickness of the bed as given in the above table is too great for the entire field included in the accompanying map. On Beaver and Ferrell creeks the amount of coal that could be mined is over 5 feet, while on Marrowbone Creek it is not over 4 feet, and nearly one-third of this is not marketable. Elsewhere in the field the bed is even thinner.

The thickness of over 5 feet as given for the Upper Elkhorn bed is due to a number of sections of great thickness from a small portion of the field. At the head of Elkhorn Creek the amount of marketable coal in this bed is close to 8 feet, while on Marrowbone Creek it is little over 3 feet. A closer approximation of the thickness of the bed throughtout the field would be about 5 feet.

ANALYSES OF COAL.

All of the coals in this part of the great Appalachian coal field are bituminous, but few are of higher grade than those found in the Elkhorn field of eastern Kentucky. They will probably rank among the best steam generators, and their coking qualities are practically assured. Chemical analysis shows that the sulphur content is uniformly low and that the amount of ash is moderate.

The following table shows the results of analyses made of some of these coals by F. M. Stanton at the United States Geological Survey fuel-testing plant at St. Louis. The samples analyzed were collected by the writer according to Survey regulations, which require that mine samples be taken by cutting a channel across a clean face of the coal bed, including everything except partings and binders over one-fourth inch in thickness. Channels are of such size as to furnish about 5 pounds of coal per foot of bed, and the material is caught on oilcloth to keep out dirt and excess moisture. The gross sample is pulverized and quartered in the mine until reduced to about one quart, which is sealed in an air-tight galvanized-iron can. The original moisture content of the coal is thus preserved until the sample is opened for analysis.

Laboratory analyses of coal samples from Elkhorn field, Kentucky.

[F. M. Stanton, analyst; sampled by R. W. Stone.]

	Name and location of coal.									
	Millard.	Lower Elkhorn.					Upper Elkhorn.		Flatwoods [illegible]	
		Pike mine.								
	H. E. Coleman, Regina.	Whole bed.	Excluding laminated coal.	Laminated coal only.	Robert Martin, Road Creek, excluding laminated coal.	Sanford Moore, Pond Creek.	Greenough mine, whole bed.	Ben Potter, Elkhorn Creek.	Cassell Fork, 7-foot top bench [illegible]	[illegible]
Laboratory number	3662	3705	3706	3702	3663	3661	3708	3828	[illegible]	[illegible]
Sample as received:										
Moisture[a]	3.00	2.90	3.35	3.19	4.73	5.27	4.03	3.96	3.[illegible]	45
Volatile matter[a]	32.22	28.59	31.76	25.83	31.62	27.74	32.46	32.37	33.[illegible]	69
Fixed carbon[a]	56.59	53.70	60.81	48.61	61.57	59.75	58.73	61.10	54.[illegible]	61
Ash	8.19	14.81	4.08	22.37	2.08	7.24	4.78	2.57	8.2[illegible]	25
Sulphur	1.06	.49	.54	.40	.71	.50	.74	.56	.8[illegible]	82
Loss of moisture on air drying	1.40	1.30	1.70	1.80	3.20	3.40	2.80	1.90	1.7[illegible]	70
Air-dried sample:										
Moisture[a]	1.62	1.62	1.68	1.42	1.58	1.93	1.26	2.10	1.7[illegible]	78
Volatile matter[a]	32.68	28.97	32.31	26.30	32.66	28.72	33.40	33.00	34.2[illegible]	27
Fixed carbon[a]	57.39	54.41	61.86	49.50	63.61	61.85	60.42	62.28	55.[illegible]	55
Ash	8.31	15.00	4.15	22.78	2.15	7.50	4.92	2.62	8.[illegible]	40
Sulphur	1.07	.50	.55	.41	.73	.52	.76	.57	.8[illegible]	83
Fuel ratio	1.76	1.88	1.92	1.88	1.95	2.15	1.81	1.89	1.[illegible]	62

[a] Proximate.

The analyses in the preceding table indicate a good grade of coal [illegible] in each of the beds from which samples were taken. They show that [illegible] the Millard and Flatwoods coals have the highest percentage of ash [illegible] and lowest fuel ratios, and that the Lower Elkhorn coal on Pond [illegible] Creek has a higher fuel ratio than any other coal from the localities [illegible] represented by the analyses. The high percentage of ash in the [illegible] samples of Lower Elkhorn coal from the Pike mine has been discussed on page 57. Moisture and sulphur are low in each of these.

Analyses made by A. S. McCreath of samples taken by E. V. d'Invilliers, Joseph Sillyman, and others are given in the following [illegible] table. They have been assembled from reports of the Kentucky [illegible] Geological Survey, reports of the Kentucky Inspector of Mines, and [illegible] private reports. The writer does not know what method of sampling [illegible] was used or what care was taken of the samples, but from the results [illegible] obtained it is suspected that they dried before being analyzed and [illegible] that in some samples the whole of the bed was not represented. It [illegible] makes a difference with the Lower Elkhorn coal whether the laminated coal is included or not, as shown in the preceding table.

Analyses of miscellaneous coal samples from Elkhorn field, Kentucky.

onstituents.	Name and location of coal.									
	Elswick.	Auxier.	Lower Elkhorn.					Upper Elkhorn.		
	Mouth of Moores Branch	Mouth of Elkhorn Creek.	Average of 22 samples.	Ferrell Creek.	Ferrell Creek.	Head of Marrowbone Creek.	Average of 9 samples.	Average of 19 samples.	Abners Fork, Ferrell Creek.	Pigeon Branch Elkhorn Creek.
	(a)	(a)	(b)	(a)	(a)	(a)	(c)	(b)	(a)	(c)
isture	0.65	0.65	1.425	2.89	7.70	0.92	1.441	1.538	7.54	1.420
atile matter	30.55	29.96	32.105	32.21	23.30	36.78	31.804	34.985	25.14	32.960
ed carbon	59.239	58.98	58.435	59.90	61.46	58.08	56.837	58.367	60.60	59.317
	8.180	9.72	7.459	4.33	7.48	4.22	9.538	4.499	6.72	5.620
phur	1.381	.69	.574	.67	.567	.47	.558	.587	.428	.683
sphorus	....	....	.0039	.003	....	.006	.0028	.0022	....	.001
Fuel ratio	1.94	1.97	1.82	1.86	2.64	1.58	1.79	1.67	2.41	1.80

onstituents.	Name and location of coal.									
	Upper Elkhorn.							Flatwoods.	(?)	
	Marrowbone Creek.		Marshall Branch.		Mullins bank, Elkhorn Creek.		Bens Branch Elkhorn Creek.	Cassell Fork.	Pigeonroost Creek.	Blowing Rock Gap road.
	(c)	(c)	(c)	(d)	(d)	(c)	(c)	(c)	(d)	(d)
sture	1.97	1.114	1.242	1.24	2.60	1.930	1.930	3.594	1.06	0.60
tile matter	33.41	34.916	35.598	38.84	34.20	36.950	36.170	35.156	37.91	39.22
d carbon	56.54	57.068	60.014	58.65	60.80	58.247	57.423	52.792	58.79	58.00
	7.57	6.230	2.610	1.26	2.40	2.380	3.880	7.750	2.23	2.16
hur	.51	.642	.536	.64	.412	.593	.597	.708	.76	.90
sphorus	.006	.004	.002	.004	....	....	....	....	.004	.005
Fuel ratio	1.69	1.63	1.69	1.51	1.78	1.58	1.59	1.50	1.55	1.48

Crandall, A. R., The coals of Big Sandy Valley: Kentucky Geol. Survey, Bull. No. 4, , pp. 108–113.
Manufacturers' Record, vol. 45, No. 23, supplement. 1904.
Private reports.
Annual reports of inspector of mines, Kentucky, 1901–1902, pp. 417–421.

Crandall explains that the high percentage of moisture and ash in analyses of samples from Ferrell Creek is due to their being taken m weathered surfaces and possibly containing infiltered dirt. It possible that the same explanation may apply to others of these alyses, for it is noticeable that the sample of coal from Bens Branch Elkhorn Creek, which was probably taken from Ben Potter's open- at the outcrop, is of lower grade than that from Ben Potter's, ich is shown in the first table, and which the writer cut from the ding, 20 feet from the outcrop, where the coal is unweathered.

These miscellaneous analyses show that the fuel ratio of the Upper khorn coal is generally lower than that of the Lower Elkhorn, but, the other hand, the average percentage of ash in the Lower Elk- n coal is nearly double that in the higher bed. The sulphur and osphorus content is uniformly low in all these analyses.

The following table is given for the purpose of comparing the Elkhorn coals with well-known eastern bituminous coals:

Average analyses of eastern bituminous coals.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
Pocahontas, semibituminous (average of 38)[a]	0.78	17.43	77.71	4.63	0.62	4.458
New River (Quinnimont), semibituminous (average of 17)[b]	.60	19.98	75.20	4.27	.67	3.763
Pittsburg coking (average of 20)[c]	1.130	29.812	60.420	7.949	.689	2.027
Lower Elkhorn (average of 22)[d]	1.425	32.105	58.435	7.459	.574	1.820
Upper Elkhorn (average of 19)[d]	1.538	34.985	58.367	4.499	.587	1.668
Clinch Valley gas coal[e]	1.180	37.398	56.732	5.602	.619	1.517
Westmoreland gas coal[e]	1.427	37.521	54.921	5.418	.713	1.464
Pennsylvania gas coal[e]	1.280	38.105	54.383	5.440	.792	1.427

[a] White, I. C., Geol. Survey West Virginia, vol. 2, pp. 695, 696, 700.
[b] Ibid, p. 670.
[c] H. C. Frick Coke Company.
[d] Manufacturers' Record, vol. 45, No. 23, supplement. 1904.
[e] McCreath and d'Invilliers, Mineral Resources of Upper Cumberland Valley, p. 145, 1888.

COKE.

How many of the coals in this region are good coking coals has not been determined, but it has been shown by tests that the Upper Elkhorn bed at the head of Elkhorn Creek, where it has a thickness of over 8 feet, makes a high grade of coke. The Northern Coal and Coke Company built beehive ovens near the head of Elkhorn Creek, coked coal taken from banks opened on the Upper Elkhorn bed in the neighborhood, and exhibited the product at the Louisiana Purchase Exposition. The following information on this subject is from the article cited above in a supplement of Manufacturers Record:

Representative samples of coke made from coal from the Elkhorn seams show the following composition, with which are given, for purposes of comparison, the compositions of cokes from other well-known regions:

Analyses of cokes from Elkhorn and other well-known coals.

District.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Phosphorus.
Upper Elkhorn, Ky	0.580	1.445	90.451	0.474	7.050	0.004
Do	.860	.914	88.679	.506	9.815	.007
Do	.142	1.033	92.744	.451	5.630	.008
Lower Elkhorn, Ky	.210	.710	90.210	.692	8.870	.009
Pocahontas, W. Va	.350	1.008	93.059	.611	4.972	
Pocahontas, Va	.348	.900	92.840	.605	5.307	
Connellsville, Pa	.790	1.310	86.880	.695	11.540	.015
Do		1.700	91.000	.470	7.300	.012
Do		1.200	87.900	.550	10.900	.015

Physical tests of Elkhorn cokes represented by the second and third samples in the preceding table were made by Mr. John Fulton, Johnstown, Pa., the well-known coke specialist, from whose report the following extract is taken:

The hardness of the Kentucky coke is so nearly equal to that of Connellsville that no serious practical difference should be mentioned. Both of these cokes (samples 2 and 3) will sustain the highest blast-furnace charges in use to-day, and in chemical purity exceed the average of the standard Connellsville coke. * * * Under these conditions of the physical and chemical properties, especially with very low volumes of sulphur and phosphorus, they are admirably adapted for use in blast furnaces producing Bessemer pig iron.

The following analyses and tests made for the Northern Coal and Coke Company at several different laboratories and plants were kindly furnished by John C. C. Mayo, an officer of the company.

Analyses of five samples of 48-hour coke and four samples of 72-hour coke made in beehive ovens of the Northern Coal and Coke Company on Elkhorn Creek with coal taken from the Ben Potter and William Mullins and banks average as follows:

Analyses of Elkhorn coke.

[A. S. McCreath, analyst.]

Constituents.	48-hour.	72-hour.
Moisture	0.187	0.151
Volatile matter	1.265	1.147
Fixed carbon	90.140	91.072
Ash	7.891	7.082
Sulphur	.517	.546

Phosphorus to the amount of 0.003 per cent was found in two of the samples.

A sample of 48-hour coke from the coal at Ben Potter's gave the following results in a physical test by John Fulton, of Johnstown, Pa.:

Physical test of Elkhorn coke.

Percentage by volume of coke	59.84
Percentage by volume of cells	40.26
Compressive strength of cubic inch, one fourth ultimate strength..pounds..	279
Height of furnace charge without crushing..feet..	111
Order in cellular space	1.25
Hardness	2.95
Specific gravity	1.75

A test of the coking qualities of the Upper Elkhorn coal, made by the United Coke and Gas Company, of Camden, N. J., from a 200-pound sample taken from 30 sacks, gave a coke of good furnace and foundry quality. The coal was crushed to pieces one-fourth to one-eighth inch in size, thoroughly mixed, and carbonized in an iron box. Analyses of dry coal and coke are shown in the following table. An analysis of by-product coke made by the Illinois Steel Company is given in the last column for the purpose of comparison.

Analyses of Upper Elkhorn dry coal and coke.

Constituents.	Coal.	Coke.[a]	By-product coke.
Volatile matter	38.72	1.20	1.02
Fixed carbon	56.71	93.01	95.55
Ash	3.94	5.32	3.43
Sulphur	.62	.47	
	99.99	100.00	100.00
Sulphur			.46
Phosphorus	.0084	.0047	.004

[a] Yield of coke on box test, 71 per cent.

Another test for the Northern Coal and Coke Company was made by the Pittsburg Testing Laboratory (Limited), with the result shown in column 3 of the next table. The Semet-Solvay Company, of Syracuse, N. Y., report as follows on a trial of the Upper Elkhorn coal, the analyses of coal and coke being given in columns 1 and 2 of the table.

A sample of Upper Elkhorn coal from the William Mullins opening was coked by the Hamilton Otto Coke Company at Duluth and gave the results shown in column 4 of the table.

Analyses of Upper Elkhorn coal and coke.

Constituents.	1. Coal.	2. Coke.	3. Coke.[a]	4. Coke.[b]
Moisture	1.12	0.26	0.17	
Volatile matter	37.95	1.68	0.00	1.72
Fixed carbon	55.70	89.67	90.84	94.80
Ash	5.23	8.39	8.99	3.48
	100.00	100.00	100.00	100.00
Sulphur	.55	.64	.49	.48
Phosphorus	.0055	.0118	.16	.008

[a] J. O. Handy, analyst. [b] W. H. Wright, analyst. Sample dried at 105° C.

Total wet coal, 35,335 pounds; moisture, 2.42 per cent; total dry coal, 34,480 pounds; toal wet coke, 23,446 pounds; moisture, 1.3 per cent; total dry coke, 23,141 pounds; yield dry coke, 67.11 per cent; total wet breeze, 1,206 pounds; moisture in breeze, 12 per cent; total dry breeze, 1,061 pounds; yield breeze, 3.07 per cent; total yield, 70.18 per cent.

By-products per 2,000 pounds of dry coal: Ammonium sulphate, 27.607 pounds; tar, 106.3 pounds; total gas, 10,000 cubic feet.

These tests, made by men thoroughly experienced in that work, show that the Upper Elkhorn coal in this part of the field produces a coke which is the equal of the standard cokes made in this country, and is superior to Connellsville coke in its very low percentage of the two impurities, sulphur and phosphorus. It is the belief of some who have experimented with it that the strength of coke made from Elkhorn coal is increased by the addition of a small amount of laminated coal in the charge.

TONNAGE.

Any estimate of the amount of coal in this field must necessarily be only approximate. It is not absolutely known how far the beds extend beneath the surface or whether the average thicknesses shown in prospects and mines are maintained for any great distance back from the outcrops. It may be assumed that a bed 2 feet thick is workable, because beds carrying less than 2 feet of bituminous coal are being mined in the United States to-day.

The following estimate of the coal now in the ground does not nclude the 3- or 4-foot bed said to be above the Upper Elkhorn coal r the 4-foot bed 500 feet above the Flatwoods coal, both of which nderlie only small areas because they are so close to the ridge tops.

The tonnage of the Elswick and Bingham coals is estimated on an rea only one-fourth that of the field, because so little is known of the haracter of these beds. The Auxier and Millard beds are better nown and are assumed to be of workable thickness under at least 0 square miles of the 130 which constitute the field. The acreage of he Elkhorn and Flatwoods coals was obtained by planimeter from he accompanying map (Pl. I), the divide at the head of Russell Fork drainage being taken as the boundary of the field.

Estimated gross tonnage in the Elkhorn coal field.

Bed and locality.	Area.	Thickness.	Amount.
	Acres.	*Feet.*	*Short tons.*
lswick	19,200	2½	86,400,000
uxier	32,000	2½	144,000,000
Millard	32,000	2	115,200,000
ingham	19,200	3	103,680,000
ower Elkhorn:			
East of Russell Fork	12,140	5	109,200,000
Russell Fork to Shelby Gap	33,825	4	243,540,000
Shelby Gap to head of Elkhorn Creek	9,150	3	49,410,000
pper Elkhorn:			
East of Russell Fork	4,000	6	43,200,000
Russell Fork to Shelby Gap	20,720	3½	130,536,000
Shelby Gap to head of Elkhorn Creek	6,425	8	92,520,000
latwoods	2,300	7	28,980,000
Total			1,146,726,000

This estimate is on the basis of a specific gravity of 1.3, or 1,800 ns per acre for every foot of coal.

These figures are so inconceivable that the idea of the amount of al estimated to be in this field can be grasped only when expressed other terms than millions of tons. The total amount of coal in e Elkhorn field is nearly three times as much as all the coal mined the United States in 1905, it is nearly ten times the amount of uminous coal mined in Pennsylvania in 1906, and is equivalent to the bituminous coal mined in Pennsylvania previous to 1902. It uld make a solid bed of coal 8 feet thick over the area represented the accompanying map or 1 foot thick over 1,000 square miles. e 92,500,000 tons of coal in the Upper Elkhorn bed between Shelby p and the head of Elkhorn Creek lacks only 1,000,000 tons of ng equal to all the coal mined in Kentucky between 1828 and 5; if loaded in 40-foot coal cars carrying 40 tons each, it would ke a train 17,522 miles long. The total amount of coal in this d, over 1,000,000,000 tons, if loaded in the same way, would make rain 217,183 miles long, or eight trains extending around the world th enough left over to make more than five solid trains reaching om New York to San Francisco.

With improved mining methods and utilization of the slack 80 or even 90 per cent of this coal may be marketed. Assuming, however, that 30 per cent—the average of present practice—will be wasted in mining, there remains a possible output of 800,000,000 tons.

MINERAL RESOURCES OTHER THAN COAL.

Sandstone.—In the coal-bearing rocks there is usually an abundance of stone at one horizon or another suitable at least for rough construction work. In this field medium to coarse grained sandstone of fair quality is to be found at many places conveniently located for quarrying. A sandstone that outcrops at the mouth of Marrowbone Creek and a little above the water on Jesse Creek was quarried at these two places by the Chesapeake and Ohio Railway, and the blocks were used in bridge and culvert construction. The sandstone is rather massive, blue-gray when fresh, and weathers to brown. Its texture varies from medium to fine. Some of the bedding is marked by black lines of carbonaceous matter, and bed surfaces often are black with carbonized vegetable fragments, including even lamellæ of coal. Mica is abundant in the rock, and brown stains extend along lines of fracture.

Shale.—Little attention has been given to the clays and shales in this part of the State. So far as known, there are no heavy beds of fire clay in this field, and most of the shales are sandy or slightly bituminous and not well adapted for brickmaking. Fine-textured, moderately fusible, and fairly plastic clay shale is required for such purposes.

Limestone.—The Newman limestone outcrops in great abundance on the north side of Pine Mountain. Its outward appearance suggests that it is a pure, high-grade limestone which, in conjunction with suitable shale, might be a source of raw material for the manufacture of Portland cement. No analyses of this stone are at hand.

PART II.—THE RUSSELL FORK COAL DISTRICT, VIRGINIA.

INTRODUCTION.

Purpose of this report.—Even at the present day there are considerable areas in the Appalachian coal region concerning which no one has very definite information. They have escaped examination because of their inaccessibility, their heavily forested condition, or their remoteness from lines of transportation. A combination of these conditions has retarded the prospecting and development of the field of bituminous coal here described, which lies in southwestern Virginia.

The extension of the Chesapeake and Ohio Railway up Big Sandy River into Pike County, Ky., drew attention to the coal field thus made accessible, and the contemplated construction of a railroad from Dante, Va., through Dickenson County made it desirable that information should be obtained as to the extent and character of the coal field in that section. This information would be valuable both to people who live in the field and to outside investors. Most of the residents of the district have very little idea of the extent of the coal or of its value, and hence are wholly ignorant of what they are selling when they dispose of their coal rights. They do not realize that a 4-foot coal bed yields 6,000 tons per acre. To them the information accumulated by this survey and imparted in this report should suggest the desirability of reserving their coal rights or of getting a fair price for their lands rather than, as formerly, selling coal rights by the acre for a merely nominal sum, in no way representing the value of the right disposed of. To outsiders interested in the discovery and development of coal resources this report should be of some value by giving the information at present available as to the character and thickness of the coal seams and their probable extent.

With this purpose in view the task of making a reconnaissance examination of the coal resources of Russell Fork of Big Sandy River during the summer of 1906 was assigned to the writer. The report on the part of the field lying in Kentucky forms the first part of this bulletin. The second part—this report—discusses the Virginia portion of the Russell Fork field.

Literature.—Published information relative to this field is exceedingly scarce. C. Newton Brown made a hasty tour through the northern part of Dickenson County and the western part of Bu-

chanan County in 1897 and says, in his report on the mineral resources of Big Sandy Valley,[a] that as a rule the people have given no thought to the matter and know very little as to the thickness, number, and extent of the coal beds. He states that the beds range in thickness from 3 to 6 feet and some of them are fine bituminous coal. He reports no facts other than these, but predicts that large areas of workable coal will be found here.

M. R. Campbell has described the geology of regions not far to the east and south in the Tazewell and Bristol folios of the Geologic Atlas of the United States and in Bulletin No. 111 of the United States Geological Survey, on the geology of the Big Stone Gap coal field. Brief reports on the coal in scattered corners of this field have been written by various men, but they have not been published.

Field work.—This report is based on six weeks' field work in the fall of 1906. The writer entered the region from Pound Gap on September 10 and made a circuit through Clintwood, across Cranes Nest River, and up McClure Creek to Flint Gap, thence along Sandy Ridge to Carrie post-office and down Fryingpan Creek and Russell Fork to Jane post-office and the Breaks of Sandy. The greater part of the field was reached by side trips from camps along this route.

The work took the form of a rapid reconnaissance with the purpose of covering the whole field described and learning as much as possible about the number and character of the coal beds and something of their occurrence, distribution, and extent. Time did not permit the working out the details of the structure or of the stratigraphy. The basis of the map (Pl. V, in pocket) accompanying this report is a drainage map made for the Clinchfield Coal Corporation by Henry Keel, of Clintwood, Va. To it the writer has added the main roads and trails, so far as he knows them. They are admittedly incomplete. Some of the roads shown are hardly passable for wagons. On this map also is shown the location of over one hundred coal openings. Most of them were visited and their locations on the map are accurately shown, but a few openings were not seen, and their location is based on descriptions by others. The openings whose locations are only approximate are numbered 5, 13, 14, 45, 46, 49, 58, 59, 61, 76, 77, 85, 86, 87, 88, 89, 90.

The field work consisted largely in running road traverses and plotting the geology on road sections. Coal banks and prospects were visited and measured wherever they could be found. All elevations were obtained by aneroid with no bench mark to check the readings. Coal outcrops are not shown on the accompanying map for the reason that it was not possible in the time allotted to this work to trace and map any particular bed or beds. Such correlations as were made are

[a] Report of Inspector of Mines of Kentucky, 1900, p. 264.

tated in the following pages instead of being drawn imperfectly on he map.

Acknowledgments.—The work was done under the direction of G. I. Ashley, who spent two days in the field and to whom the writer is ndebted for helpful suggestions in the preparation of the report. 'o the Clinchfield Coal Corporation, and particularly to W. D. 'yler, land agent, and H. B. Wright, engineer in charge, of the ame corporation, acknowledgment is made for assistance in the way f maps and information, and also for personal courtesies. Mr. Iardaway, manager of the Cranes Nest mine at Georgel, Va., added reatly to the completeness of the report by furnishing many sections neasured by himself at points where the coal can not now be seen. ames W. Fox, of New York, and John C. C. Mayo, of Paintsville, Ky., furnished private reports by H. W. Rietz, Jansen Haines, and thers, which contain notes on parts of the area, and for which cknowledgment is made. The South and Western Railway kindly upplied topographic maps of routes surveyed across Dickenson 'ounty. D. E. Llewellyn, of Wise, Va., has provided the writer with naps and other data. C. W. Dodge, jr., assisted in the geologic work uring the first two weeks. An attack of typhoid fever prevented his nishing the season, but he spent part of the following winter in the ffice preparing the illustrations for this report. To each of these gentlemen the writer acknowledges his indebtedness, and to the inhabitants of the district he extends his thanks for courtesies and assistance rendered in various ways.

GEOGRAPHY.

Location.—The area discussed in this report is that part of the rainage basin of Russell Fork of Big Sandy River which lies in irginia. It includes Dickenson County and adjoining portions of chanan and Wise counties. The area extends from the head of ssell Prator Creek, near Grundy, to the head of Pound River, at ack Mountain, and is bounded on the other two sides by Pine untain and Sandy Ridge. It contains about 550 square miles of avily wooded, thinly populated, mountainous country.

Surface relief.—Sandy Ridge, the southeastern boundary, has a neral elevation of 3,000 feet. Pine Mountain, called locally "umberland Mountain," having an equal elevation and separating rginia and Kentucky, forms the northern and western boundary. ack Mountain, at the head of Pound River, attains an altitude of 00 feet and is the highest point in the field. The divide between ssell Fork and Levisa Fork is from 2,000 to 2,500 feet above sea. e general elevation of the main streams is 1,500 feet, and the lowest

point is where Russell Fork passes through the Breaks at the northeastern end of Pine Mountain. The elevation on the State line at the mouth of Grassy Creek is approximately 900 feet.

For the most part the country is made up of steep-sided, narrow-topped ridges, and may be classed as mountainous. The ridges between Fryingpan, Lick, and McClure creeks are examples, and Big Ridge, as it is called, between McClure Creek and Cranes Nest River, is a strong feature of the topography. It is 15 miles long, and rises from 500 to 800 feet above the creeks, which are from 1 to 4 miles apart. The crest of the ridge is from 2,100 to 2,500 feet above sea level and varies scarcely a quarter of a mile from a straight line throughout its length.

There are no level areas of great extent in this section of the State, the largest being some of the flat tops of the ridges, which are comparatively level for a mile or more, but not over a few hundred yards wide. The valley bottoms are narrow, often affording little more than room for a road along the side of the stream.

Drainage.—As the area here described is the basin of Russell Fork all the drainage passes into Kentucky through the Breaks of Sandy at the north end of Pine Mountain. The principal streams tributary to Russell Fork are Pound River, McClure Creek, and Fryingpan Creek. Pound River, the largest, rises at Black Mountain on State-line Spur and flows northeast parallel with Pine Mountain for 25 miles. Cranes Nest River, a fork of Pound River, is of about the same size as McClure Creek, each having a basin about 20 miles long. The winding courses of the streams make their total lengths much greater than the length of the basins. In this report the "right" and "left" sides of a stream are relative to the position of a person facing *upstream*, thus conforming to the usage of this region.

Forests.—Much of this country is still covered with a fair growth of typical southern Appalachian hardwood forest. Cleared tracts are not at all extensive. Chestnut, yellow poplar, white and red oak, maple, beech, ash, hickory, and sycamore are common. Papaw, buckeye, cucumber tree, and black walnut are less common but not rare. Black walnut trees of any considerable size are scarce and bring a high price, though not many years ago they were cut up for fire-wood and fence rails.

Lumbering is fast stripping some of the best stands of timber, and at the present rate of increase in the industry the day is not far distant when many hillsides, worthless for any other purpose, will be cleared and left bare of timber or soil. Logs to the number of 30,000 or 40,000 were jammed in the Breaks for four years and may have retarded the lumber business in that section temporarily, but the jam broke in January, 1907. On Pound River near the mouth of North and South forks a steam tramroad has been built, portable

·mills have been introduced and logs are coming out at a rapid
e. The lumber is hauled by the tram to the railroad at Norton.
'he timber in this country is sufficient to attract considerable attion and should be the basis of a thriving industry, but with the sent wasteful and unscientific methods of lumbering a once valu- e asset will soon be exhausted and the region will be left in a dition unfavorable for the further production of forest growth. the area lies near the heads of the river the resulting increased d danger will not be so great here as it will be in Kentucky.

'he timber resources of the section described are sufficient in ntity and quality to support any coal-mining industry that may leveloped here.

'ettlement.—Dickenson County has an area of 324 square miles l a population of 7,747. The area of the Russell Fork basin in ginia is 550 square miles and the population probably does not eed 10,000. The settlements are confined to the valleys and are very small, only one having a population of more than 100 people, l that is the county seat, Clintwood, which numbers 255. There is y one colored resident in Dickenson County, a little girl living at ysi.

'arming and lumbering are the principal occupations of the people. n is the chief crop and is of necessity raised in small patches on p hillsides.

lccessibility.—There is no ready access to this country except by e gap in the surrounding mountains. Pine Mountain, State-line ır, and Sandy Ridge form a continuous barrier on three sides, with eneral elevation of 3,000 feet, while the fourth side, the divide ween Russell and Levisa forks, is but little less of a barrier.

Vagon roads are not numerous. One of the principal roads is from mps Creek over Sandy Ridge, down Fryingpan Creek to Russell k, down that stream to the mouth of Russell Prator, and then over hills to Grassy Creek and through the Breaks to Elkhorn City, . The road from Grundy comes down the Russell Prator, crosses ssell Fork at the mouth of McClure, crosses the hills to the mouth Cranes Nest, and follows the crest of the ridge to Clintwood. It s up Georges Fork, down Hamilton Creek to Pound River, and iding follows up both forks to Flat Gap. A road from Pound ls over Pound Gap to the head of Elkhorn Creek, Ky., and another s up Indian Creek to Glamorgan and Wise.

Entering the region from Dante the road crosses either Flint Gap Trammel Gap, goes down McClure to a point 2 miles below the ıth of Caney Creek, crosses to Cranes Nest River, and then up ıg Branch to Clintwood. From Clintwood one may continue th down Brush Creek, cross Pound River, and climb the mountain Blowing Rock Gap, which leads to Ashcamp, on Elkhorn Creek, in

Kentucky. Traveling by wagon on any of these roads is slow. The customary method of traveling in this country is on horseback. Haul roads and bridle paths are numerous, so that almost any point is accessible by these.

The nearest railroads are the Clinch Valley division of the Norfolk and Western Railway on the south and the Big Sandy branch of the Chesapeake and Ohio Railway at Elkhorn City, Ky., on the north. A railroad into the region from the north through the Breaks could be built at considerable expense. The South and Western Railroad has a route surveyed through the Breaks to the mouth of Cranes Nest River with a maximum compensated grade of less than 1 per cent. This route, which would connect the railroad at Dante with the Chesapeake and Ohio at Elkhorn City, extends up McClure to Trammel Gap, where Sandy Ridge would be pierced by a long tunnel. Another feasible route would be up Dumps Creek, under Kisers Gap by a tunnel, and down Fryingpan Creek. A narrow-gage steam railroad extending from Norton to Pound is used exclusively for lumbering.

GENERAL GEOLOGY.

STRATIGRAPHY.

GENERAL STATEMENT.

The rocks of this field belong to the Pottsville group of the Carboniferous. Three formations are represented in whole or in part. The lowest is the Lee conglomerate. This is overlain by the Norton formation, which makes the surface of the greater part of the area. The lower members of the Wise formation cap some of the higher portions of the ridge along the southern and eastern boundary of the region. The Lee conglomerate is about 1,000 feet thick, the Norton approaches 1,100 feet, and 200 or 300 feet of the Wise formation are present, making a total stratigraphic section of about 2,400 feet. These formations are described in detail.

LEE CONGLOMERATE.

A sandstone and conglomerate, 1,000 or more feet thick, which is prominent in this part of the Appalachians, is known as the Lee conglomerate, named from Lee County, Va., where it is conspicuous in the Cumberland escarpment. This is composed largely of massive sandstone, but may contain some thin sandy or shaly beds. Two or three coal beds have been found in it at various places. The name conglomerate was applied to this formation because some portions of it, particularly the top and bottom, carry considerable quantities of

hite quartz pebbles up to the size of a robin's egg. The for-
as a whole weathers to a grayish
nay be somewhat iron-stained on the
ınd is coarse grained. Cross-bedding
ıonly found near the top of the for-

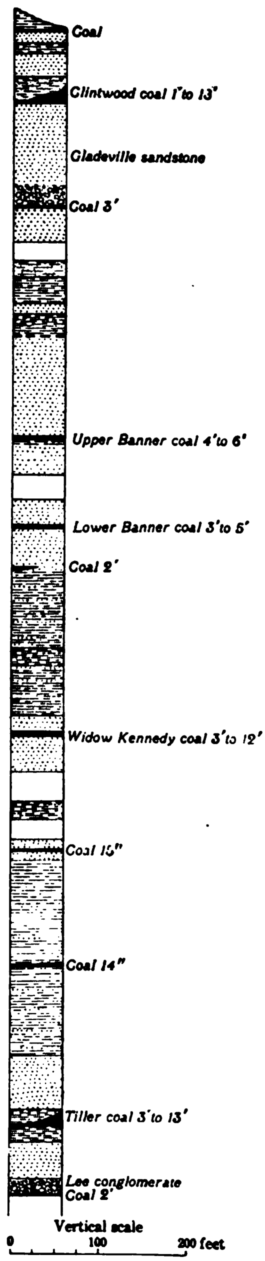


FIG. 15.—General section of rocks in Dickenson County, Va.

.ee conglomerate is exposed along the
le of Pine Mountain (Cumberland
in) from State Line Spur to the
of Sandy, where it has a thickness of
,000 feet. In the gorge known as the
the formation is exposed in sheer
veral hundred feet high. The fault
ıe west side of Pine Mountain throws
in air, so that the base of the forma-
seen at Pound Gap and a little above
s Gap. In fact, the bottom of the
on forms much of the crest of the
in. North of the river the amount
lacement along the fault decreases,
Cow Fork of Grassy Creek it is so
hat the escarpment is lost and the
the formation is but little above
vel.
onglomeratic character of the forma-
n be seen near the mouth of Camp
, a tributary of Russell Fork, at the
and along the crest of Pine Moun-
here in places the surface is strewn
uartz pebbles weathered from the
the Lee.
Russell Fork above the mouth of In-
eek a massive sandstone which car-
ite quartz pebbles and is believed to
op of the Lee is exposed for several
At the mouths of Indian and Hurri-
eks it forms cliffs 100 feet high and.
gradually to the east, keeps above
ıearly to the heads of the streams.
ɔ of the Lee, according to a hurried
rrelation, is but a few feet above
post-office, on Russell Fork, and
water level one-half mile above
ıear the coal bank of Isaac J. Hurt.
ntification of the Lee on the head of Russell Fork is based on

the close lithologic resemblance to its occurrence in Pine Mountain and on the impression gathered by riding over the country that the rise of the rocks in this corner of the county ought to bring the Lee to the surface. Confirmatory paleontologic evidence was not obtained.

NORTON FORMATION.

A series of sedimentary rocks consisting of sandstone, shale, and coal, and having a thickness of 1,000 feet or more, lies above the Lee conglomerate and is known in this part of the Appalachians as the Norton formation. It was first described by M. R. Campbell in Bulletin No. 111, on the Big Stone Gap coal field of Virginia and Kentucky. He ascribes a thickness of 1,280 feet to the formation and defines it as lying between the Lee conglomerate and the Gladeville sandstone. The formation probably varies in thickness, for there is some disagreement among sections containing it: the sections in the bulletin just mentioned and in the Bristol and Estillville folios by the same author are not alike, and the section measured by the writer is a little different from any of the others.

According to a section of the rocks measured by aneroid from Trammel Gap to Dante on the edge of this field, to which was added the record of a diamond-drill hole at Dante, the thickness of the formation is 1,060 feet. This estimate is based on an assumption that a heavy sandstone found in the drill hole 257 feet below the surface is the top of the Lee conglomerate, and that a sandstone carrying white quartz pebbles and exposed in Trammel Gap is the Gladeville. The base of this conglomeratic sandstone is only 250 feet above the Upper Banner coal, and this raises a question as to the correctness of the correlation, as Mr. Campbell has described the Upper Banner as being 400 feet below the Gladeville sandstone.

The Gladeville has not been described as conglomeratic, but always is referred to as a massive sandstone about 100 feet thick. As this conglomeratic bed at Trammel Gap is the nearest approach to a massive sandstone found in the ridge above the Upper Banner coal, and as it is at the same elevation above the coal as the massive Gladeville in the ridge between Cranes Nest River and Pound River, the writer has accepted the correlation of the bed bearing quartz pebbles in Trammel Gap as the Gladeville, thus obtaining an almost direct measure on the thickness of the formation.

So far as known a detailed section of the Norton formation has never been published. That which follows is based on a fairly complete section seen at Dante, Russell County, on the south side of Sandy Ridge, and on shorter sections measured at various points in Dickenson County:

Section of Norton formation.

	Feet.
	3
tone, thin-bedded	80
	60
ll bloom seen	1
tone, massive	100
er Banner	5
tone, shaly, and shale	80
tone	20
er Banner	3–4
tone, massive	50
	2
tone and shale	190
ow Kennedy	6
tone	30
and thin sandstone	90
tone carrying 15 inches of coal	20
tone and shale	230
tone, massive	60
	15
	3–15
	15
	1,063

this it appears that the Widow Kennedy coal is approxi- 50 feet, the Lower Banner coal 700, and the Upper Banner above the Lee conglomerate.

GLADEVILLE SANDSTONE.

is a question in the mind of the writer as to the identifica- he Gladeville sandstone in Sandy Ridge, where the greater :he above-described section was measured. Nothing in the sely resembles the Gladeville as it is conspicuously developed Wise, Clintwood, and the mouth of Cranes Nest River. Nickels Gap, near Puncheon Tree Branch of Cranes Nest e Upper Banner coal is 250 feet below the base of the Glade- dstone. In this part of the county the Gladeville is 100 k, makes strong ledges, and strews the surface with large hich are conspicuous because of their abundance and gray 'he rock is coarse grained, resembling the Lee in all respects ıat, so far as observed, it is not conglomeratic. At the same above the Upper Banner in Sandy Ridge is found a sand- ıich carries a few quartz pebbles and which it is assumed he equivalent of the Gladeville, although, according to Mr. l, the interval between the Gladeville and Upper Banner point a few miles farther west is 400 feet, or 150 feet greater interval here.

WISE FORMATION.

The lower portion only of the Wise formation is found in thi area. Its extent and distribution is not known because the Glade ville sandstone has not been traced over the whole field. It occur only in the tops of the ridges except in the vicinity of Clintwoo where it is brought down to an elevation of about 1,800 feet by structural depression. From Clintwood northeast the Wise forma tion caps the ridge for several miles, or until the Gladeville rise to the top near the mouth of Cranes Nest River. It is probable that the Wise formation also makes part of the crest of Sandy Ridge and of Big Ridge between Cranes Nest and McClure creeks.

The Wise formation is composed of sandstone and shale like the Norton formation and contains a few coal beds. One coal bed which lies at or near the base of the formation attains a thickness of 8 feet on Lick Fork and Georges Fork near Clintwood.

STRUCTURE.

GENERAL STATEMENT.

Second in importance only to the determination of the amount and quality of coal in a prospective field is the detailed determination of the structure of the beds in that field. On this depends the proper location of development work for economical exploitation of the coal, for natural drainage of the mines, for favorable grade to loaded cars, and other points which make coal mining a paying or a losing proposition.

The determination of structure which shall be of any value to mining engineers or others interested in the development of a coal fiel must be made with considerable care and accuracy. Frequent expos ures of the reference stratum or of the deformed surface bein mapped are necessary to the success of the work, and if the baromet is used for elevations it should be checked regularly at some benc mark of known elevation.

In this field, covering 550 square miles, there is no bench on whi to check the barometer readings, and, on account of the heavi wooded character of the country and undeveloped condition of t coal resources, it was not possible to carry the correlation of any pa ticular stratum over the entire field. Consequently in the six wee given to the work it was not possible to work out the structure detail.

DESCRIPTION.

For the most part the rocks in this area lie comparatively fl The average dip will scarcely exceed 50 feet to the mile. Or

the general features or most conspicuous structure will be described. From the crest of Pine Mountain to Pound River and Russell Fork below the mouth of Pound River the rocks dip strongly to the southeast at angles decreasing in greatness toward the southeast. At the top of the mountain the conglomerate and massive sandstone at the base of the Lee dips to the east at angles as high as 25°, whereas near Pound River the dip is less than 10°. This carries the Lee conglomerate rapidly below the surface, so that it is not seen east of the river except below the mouth of Pound River on Russell Fork.

In the triangle between Pound River, Cranes Nest River, and the county line the structure as shown by the Gladeville sandstone dips in a general way toward Brush Creek or a point on Pound River north of Clintwood. In other words the Gladeville is lowest on Brush Creek or in that vicinity, a little higher at Clintwood, and rises to the southwest to the head of Lick Fork, and to the northeast reaches the top of the ridge near the mouth of Cranes Nest River. This makes a syncline or basin along Pound River.

In that portion of Wise County which is included in this discussion the syncline along Pound River is readily recognized. The axis seems to lie between North and South forks and the lowest point is near the junction of the two, for the rocks dip down South Fork, Indian, Bowlecamp, and Mill creeks.

Throughout the rest of the area under discussion, from Sandy Ridge to Cranes Nest River, the rocks, as far as could be discovered in a hurried reconnaissance, dip generally to the north and northwest. There are some minor interruptions, such as the south dip on Russell Fork near the mouth of Indian Creek and on Russell Fork from Birchleaf post-office to Duty Branch, but these are not thought to be numerous or extensive.

FAULTS.

It is well known that a great fault extends along the west side of Pine Mountain for many miles, interrupting the continuity of the Virginia and Kentucky coal fields. The effect of this overthrust fault is very plain on the Virginia side of the mountain, for it tilts the rocks up to an angle of 25° and brings all of the Lee conglomerate to the surface. This fault is on the Kentucky side of Pine Mountain, but north of the Breaks of Sandy it crosses the State line on Grassy Creek and is marked by an escarpment which decreases in height toward the northeast until on Cow Fork it is scarcely recognizable. It is possible that the fault terminates in a northward-plunging anticline on Levisa Fork, though such an anticline, if it exists, must be a very minor feature as compared to the fault.

An escarpment 100 feet or more in height on the flank of Pine Mountain near the head of Skeet Rock and Lower Twin branches

suggests that it is a fault face, but for lack of time and because it beyond the limits of the coal beds, it was not studied. The road ru along the crest of this escarpment for some distance. A notch in tl crest of Pine Mountain, known as "Skags Gap," suggests cross faul ing in the ridge. One side of the notch as seen from the south nearly perpendicular, and in that way differs from the other gaps.

Parallel faults 75 yards apart and trending N. 40° W. were fou at the mouth of Pound River. The amount of displacement was n ascertained. One of these faults crosses Pound River at the dam a directly under the gristmill which is situated here. On the low side of the dam is the Lee conglomerate, rising 40 feet above t water, while on the upper side beds of shale dip away from the fau Angular blocks of the Lee are seen in the fault at the door of the mi Sandstone overlying the shale dips upstream for a short distan but at the ford, less than one-fourth mile above the mill, the dip downstream.

The second fault makes a displacement in the Lee and exten along the west bank of Russell Fork, crossing Pound River at i mouth. This fault is conspicuous at low water, for the rock floor Pound River breaks off abruptly in a straight line into the deep water of Russell Fork. Time did not permit of a determination the extent of these faults. The accompanying illustrations (Pl. V *A* and *B*) show the faulting better than it could be shown by a further description.

A small fault making a displacement of about 20 feet in a massi sandstone was noted at the ford just below Colley post-office, near t mouth of Fryingpan Creek. On Priest Fork, less than one-four mile above the mouth, the dips in some of the outcrops are very stro and a cliff in the stream above John Kiser's house shows some d turbance which seems to indicate a small fault. A coal opening abo the road near Kiser's house also shows a little displacement of t strata. It is not known that there is any relation between the faul at these two places, but the suggestion that there may be is strengt ened by the occurrence of a very sharp little fold at the third be in Russell Fork above Murphy. These three points are in line a may be related.

On Russell Fork, about 1 mile above the mouth of Hurrica Creek and near Spencer Ball's house, there is some indication of fault. A massive sandstone, supposed to be the top of the Lee, whi can be traced from the head of the river to this point, gradually d creasing in elevation, here suddenly disappears, and shale standi at high angles is seen at the same elevation. A short distance bel Ball's the heavy sandstone ledges appear again and continue to t mouth of Hurricane Creek, where the top of this conspicuous strat is about 70 feet above the creek. The dip continues downstream f

A. FAULT LINE SHOWN BY ROCKS IN BED OF STREAM, MOUTH OF POUND RIVER.

B. FAULT AT MOUTH OF POUND RIVER.

The mill conceals brecciated zone. Lee conglomerate on right, shale on left of picture.

a short distance, but reverses, so that the same sandstone makes a cliff 100 or more feet high at the mouth of Indian Creek. Although highly tilted strata or faults were not seen on Indian Creek, it is notable that there is a possibility of the continuance of the above-described disturbance a little below Duty. The heavy sandstone, supposed to be the Lee, on Caney Fork of Indian Creek, dips gently downstream to a point about one-fourth mile below the mouth of Caney. There the conspicuous ledges disappear, and it is said the large coal bed in this vicinity shows evidence of disturbance. Farther downstream the massive sandstone ledges appear again, but they are dipping strongly upstream. This is not sufficient evidence for drawing the continuation of the fault seen at Ball's across to Indian Creek, but to those considering investment in this part of the field the suggestion may be of value.

At Haysi, a few rods east of C. M. Heyter's store, sandstone, shale, and thin streaks of coal are exposed in the highways, standing vertical and striking north and south. Just west of the store, in the road in front of Mr. Garrett's house, there is a 2-foot coal which dips 70° and strikes N. 65° W. In the head of a ravine on Mrs. Winnie Scyphers's land and below Garrett's house the rocks are greatly disturbed and indicate proximity to a fault. Sandstone at the head of the ravine stands vertical, and a few rods below is shale which is both contorted and vertical. Between these outcrops coal dipping only a few degrees is exposed under a roof of jointed sandstone. The relation of this sandstone to the other rocks suggests that its broken condition is due to the strain of faulting. Farther down the ravine the rocks are horizontal.

It is possible that other minor faults or sharp folds of small extent may be found on closer investigation of the field.

COAL RESOURCES.

GENERAL STATEMENT.

On account of the undeveloped condition of the coal resources of this region and because of the reconnaissance character of the survey, it is not possible for the writer to name and describe the extent of the various coal beds occurring in the area. Many of the coal outcrops lie several miles from the next, and in the wooded condition of the country it was impossible to carry correlation over distances so great. Certain beds were traced throughout small areas, but in some parts of the field no horizon was recognized with certainty.

Five coal beds of economic importance were recognized and will be referred to by name wherever the identity is established. The lowest of these is a bed from 3 to 15 feet thick which, in the author's opinion, occurs a few feet above the top of the Lee conglomerate. Paleonto-

logic or other evidence has not yet been obtained to confirm this point. This horizon is below the surface of the greater part of the area, but is exposed on the head of Russell Fork and its tributary, Indian Creek. Here the coal has a thickness of 8 feet or more at a number of openings. Because of the interest of S. J. Tiller, postmaster at Duty, Va., in the development of this coal, it will be called in this report the Tiller coal. It probably corresponds to the Elswick coal of the Elkhorn field of Kentucky.

The Widow Kennedy coal, which has been mined for a number of years at Dante and is exposed east of Tacoma, Va., is 400 to 450 feet above the Lee conglomerate. So far as the writer's limited observations go this coal has sandstone for both roof and floor. The roof sandstone at some places is fractured by numerous joints. The bed varies greatly, thicknesses of 3 feet and 12 feet having been seen in the same mine, and at another point it decreases from 7 feet to 1 foot in 50 yards. Faulting strains or other forces seem to have disturbed this coal more than the others, and in many places it is crushed, contorted, and filled with balls and bands of clay, so that its value is greatly decreased.

Approximately 700 feet above the Lee conglomerate is the Lower Banner coal, which is mined at Dante and Toms Creek. This coal is about 4 feet thick and occurs above 50 feet of massive sandstone. It is little known in the area described, and the fact that it has not been found elsewhere may indicate that it is thin and unimportant.

One hundred feet above it is the Upper Banner coal, 4 to 5 feet thick, which is widely known in Dickenson County by numerous prospects. A sandstone parting 1 to 3 inches thick occurring in the upper part of the bed is a peculiar characteristic of this coal.

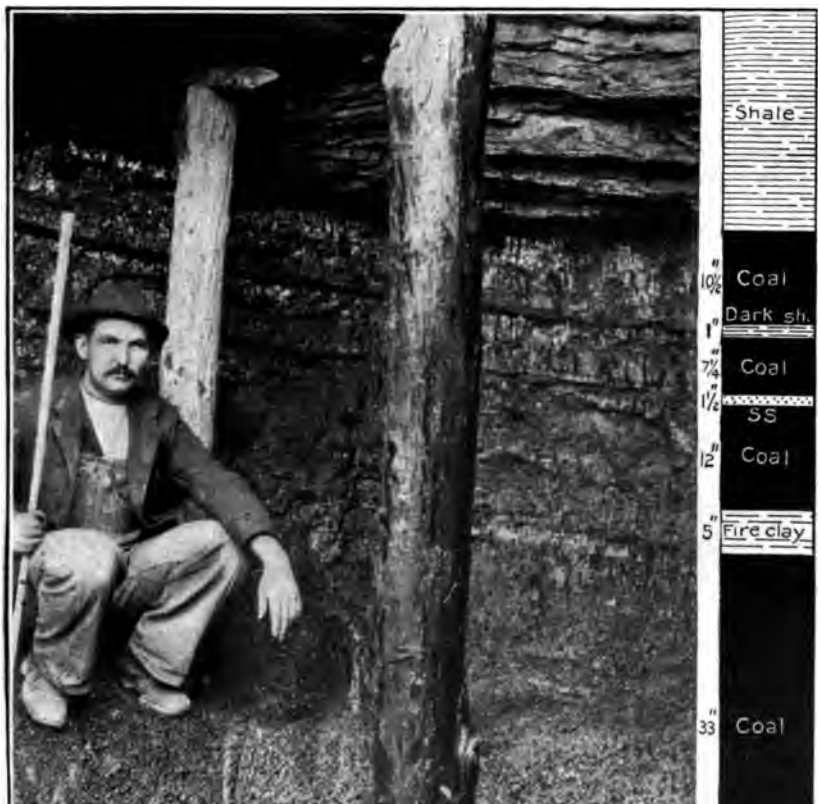
In the vicinity of Clintwood a coal bed 5 to 9 feet thick occurs just above the Gladeville sandstone and has been opened in a number of places. The fuel supply of the county seat comes from this bed. The writer can not definitely correlate it with any seams previously described, and in this report will call it the Clintwood coal. Its greatest development is west of Clintwood.

A description of the exposures seen at prospect trenches, coal banks, and natural outcrops in all parts of the area will give an idea of the character and distribution of the coal beds. To facilitate description the field will be divided into four parts, namely, the drainage basins of Pound River, Cranes Nest River, McClure Creek, and Russell Fork.

RUSSELL FORK.

General statement.—The section of the field described under the heading Russell Fork includes all the tributary drainage of Russell Fork on the east from its head to Grassy Creek, at the State line,

A. ISAAC HURT COAL BANK, RUSSELL FORK.



B. UPPER BANNER COAL AT FLOYD VIERS, LOW GAP BRANCH.

B from photo loaned by H. Hardaway.

and Fryingpan and Lick creeks on the west. Most of this section is very thinly settled and little prospecting has been done for coal except on Indian Creek, where there is an unusually thick bed, and on Fryingpan Creek near Bucu post-office.

Council.—A coal was once opened about 20 feet above the store at Council, on the head of Russell Fork, but the opening is caved now. One-third of a mile above Council, beside the road and only a few feet above the creek, there is a coal bank belonging to Isaac J. Hurt, where coal is mined regularly. An entry has been driven 100 feet N. 10° E. slightly up the rise of the coal, which dips northwest. The bed is 5½ feet thick (1)[a] and contains 2 inches of clay and 30 to 36 inches of laminated coal in the middle. It has a sandstone roof and floor (Pl. VII, *B*).

The term "laminated" used in this paper is applied to coal which is crushed, soft, and flaky, which slacks readily and is high in ash. "Rash" is another word for the same thing. In places the laminated coal is crumpled and has many smooth, polished surfaces. The evidence indicates that it is the result of lateral movement in the inclosing rocks.

A few rods upstream from the Hurt coal bank the sandstone which forms the floor of the coal is seen to be of sugary texture and finely conglomeratic. The white quartz pebbles and the general rise of the rocks lead to the conclusion that this is the Lee conglomerate. If so, this is a coal not elsewhere described, for the first coal bed known above the Lee conglomerate in Virginia is the Jawbone, which is described in the Bristol folio as 150 feet above the Lee conglomerate. As already stated, this will be called the Tiller coal.

Below Council this coal is higher above the creek and the conglomerate is conspicuous and abundant, making ledges on both sides of the stream. Noah G. Ball opened the coal back of his house and 100 feet above the creek, but it is concealed now. The thickness is reported as 7 feet. About 100 yards below Ball's, in a hollow on the north, there is a prospect which shows a horizontal shale roof and 5 feet of coal with bedding highly tilted. Three-quarters of a mile below Ball's the ledges of Lee conglomerate disappear and shale appears at the same elevation. This change is one-eighth mile above Spencer Ball's and is attributed to a fault. Three hundred yards below Spencer Ball's an outcrop in the road shows shale standing nearly vertical with horizontal shale on both sides. The disturbance from the original position of the beds at this point is apparent. The conglomerate appears again shortly and continues to the mouth of Hurricane Creek, where it makes a conspicuous ledge 70 feet high.

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[a] Figures in parentheses correspond to locations numbered on the map (Pl. V) and to coal sections numbered on accompanying group of coal-section figures. A letter following the figures means that two or more sections were measured at one opening.

It is reported that coal has been found on top of the conglomerate in a hollow near the mouth of Hurricane Creek. There is a strong dip to the rocks down Russell Fork for a short distance, but it reverses, bringing up the Lee, which makes a cliff at the mouth of Indian Creek.

In the bank of Russell Fork at the north end of a suspension bridge just below the mouth of Indian Creek there is a 22-inch bed of coal under a 100-foot ledge of sandstone supposed to be the upper part of the Lee. Fossils found in the roof shale were too poor to determine the exact stratigraphic position of the bed.

Indian Creek.—Ledges of heavy sandstone supposed to be the top of the Lee conglomerate are exposed on Indian Creek from its mouth to at least a mile above the mouth of Caney Fork and 2 miles above Duty post-office, on the main fork of the creek.

Near the three forks of the right fork of Indian Creek, on J. H. Musick's land, and 200 feet above the stream, there is an opening which shows a coal bed 12 feet thick containing two shale partings which are 22 and 33 inches thick (2). This section was obtained from H. Hardaway and is believed to represent the coal which lies on top of the Lee.

Near Doctor Comb's house, on the left fork of Indian Creek, there is an opening on the left side of the creek on a coal bed reported by Mr. Hardaway to be nearly 5 feet thick (3). Only 4 feet could be seen at the time of the writer's visit. If this is not the same as the Tiller coal, it is not much over 100 feet above it.

On the Van Sutherland tract at the head of the right fork of main Indian Creek there is an opening which exposes a bed, supposed to be Tiller coal, 12 feet 5 inches thick (4). The thickest parting in this bed is 18 inches, but much of the coal is inferior. The shale roof is fossiliferous and shows concentric structure.

In Cane Gap an opening driven 30 feet S. 10° W. up the rise shows the Tiller coal 15 feet 4 inches thick (5), according to a measurement by Mr. Hardaway. The bottom part of this, 4 feet 10 inches thick, is fine solid coal and the remaining 10 feet contains 4 feet of clay and shale. In the first hollow south of Cane Gap and just over the ridge from Sutherland's there is an opening close to Elijah Rasnick's house which, according to Mr. Hardaway, is driven 50 feet S. 70° E. and shows a bed 6 feet 2 inches thick (6) similar to the lower part of the bed at Cane Gap. The upper part of the bed is concealed. Directly over the ridge from Rasnick's on Caney Fork drainage a drift was once run 20 feet S. 25° E., but is caved now. Only 6 feet 1 inch of the lower part of the bed was exposed (7), of which 18 inches is curly and flaky.

At the head of the left fork of Caney Fork above S. J. Tiller's house this coal has been opened in several places. Near the head of

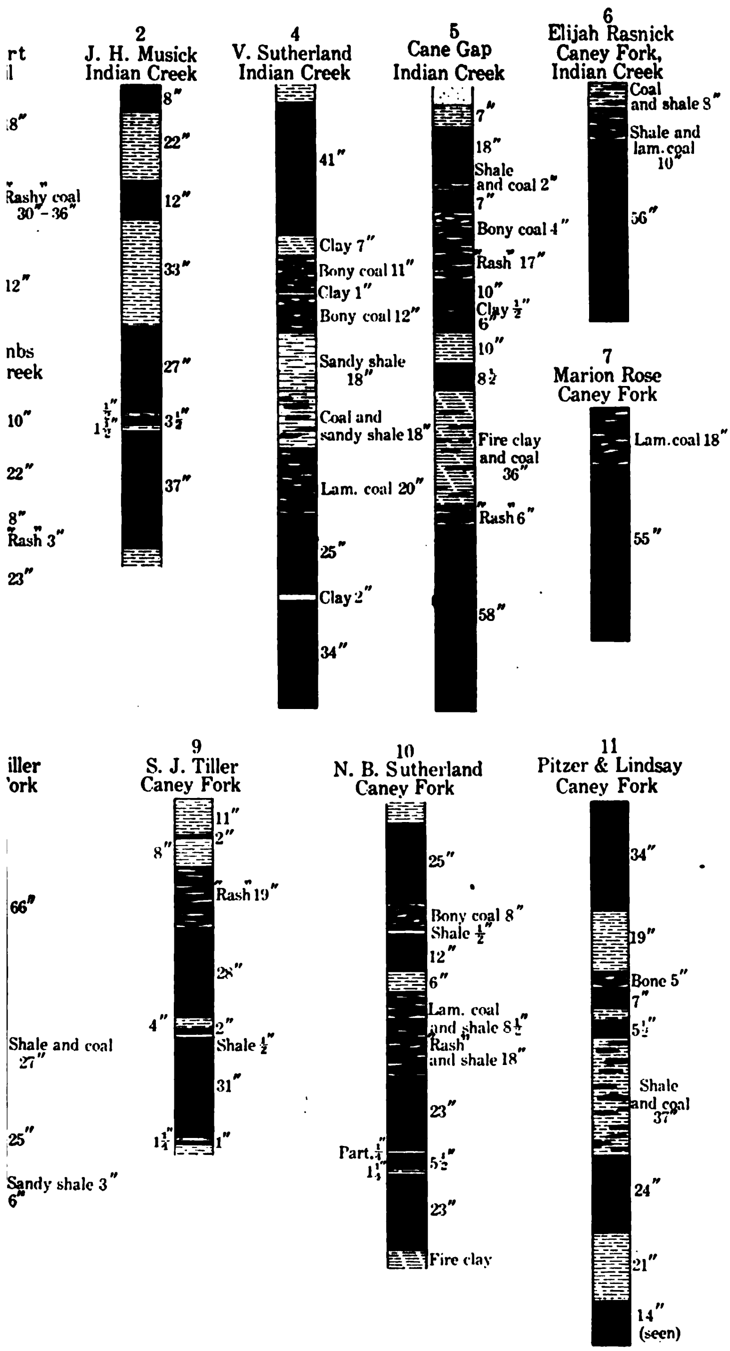


Fig. 16.—Sections of Tiller coal.

the fork Hiram Tiller has dug into the outcrop and reports the bed 13 feet 4 inches thick; the writer saw over 11 feet of coal, but the bed may not have been entirely exposed (8). In the woods 110 feet above the creek an opening was made to obtain fuel for a locomotive used in logging. A "switch back" was built to the entrance and an entry driven east 120 feet on the coal. The bed is 8 feet thick and 5½ feet of it was mined (9).

On Caney Fork above N. B. Sutherland's house this bed has a thickness of 11 feet (10) and is not heavily burdened with shale or clay partings. This section was measured by Mr. Hardaway. According to his classification it contains 26 inches of laminated and rashy coal and shale. The writer did not see the coal at this point, but presumes the laminated coal referred to is a bony coal and that the rash is a soft, crushed, flaky coal. One-half mile below Sutherland's on the right of the creek an opening about 100 feet above the water has been driven S. 45° E. on the same bed, which is a trifle less than 8 feet thick. In a field on the point of the hill on the left, 1 mile above the mouth of Caney Fork, the David Tiller pit driven west down the dip shows the coal just 8 feet thick but the middle 3 feet carries 3 partings which aggregate 17 inches of shale.

Just below the forks of Caney Fork and less than 1 mile above Indian Creek an opening on the west of the stream close to the road is reported by Mr. Hardaway to have shown the Tiller coal over 14 feet thick (11). This is known as the Pitzer and Lindsay opening. When visited by the writer this pit was partly caved and only the upper part of the section could be verified. On the north side of a hollow which joins Caney Fork on the west side at this point there is an exposure at water level of 30 inches of coal under a sandstone roof. Although this is 60 feet lower than the Pitzer and Lindsay opening it is supposed to be the top bench of the same coal brought to water level by a strong northwest dip which is apparent at the last mentioned exposures.

S. J. Tiller reports that a 4½-foot bed of coal has been opened in this vicinity about 100 feet above the big coal bed, but it is nowhere accessible at the present time. He also states that an 18-inch bed has been seen at water level near the mouth of Caney Fork. It was not observed by the writer, but if the correlation is correct this would be the same as the 22-inch bed at the mouth of Indian Creek. Between the mouth of Indian Creek and Abners Branch, a mile below, there is a coal bloom at the highest point in the road on the south side of the creek. Probably it is an unimportant bed of small thickness.

Bee.—The rocks rise rapidly up Abners Branch and it is possible that an 18-inch coal bed exposed about 75 yards up the hollow back of Bee may be the same as that just mentioned. At John Burrill's

in the gap at the head of Abners Branch an outcrop shows 17 inches of coal under 20 inches of shale and a sandstone roof (12).

Murphy.—The only coal seen on Russell Fork between Abners Branch and Fryingpan Creek is a small outcrop on Little Pawpaw Creek 300 yards above Robertson's house. Here 15 inches of coal is exposed under a ledge of sandstone close to water level. The whole bed may not have been seen. On the opposite side of the branch and a few rods farther up there once was an opening which is reported to have shown 3 feet of coal. It is said that there is a bed exposed 3 miles up Little Pawpaw Creek, where Charles Green gets fuel for his sawmill. Two feet of coal is reported back of Samuel Deel's house just below Murphy, but it is not now exposed.

Fryingpan Creek.—At the gap between the heads of Fryingpan and Indian creeks on the road from Carrie post-office to Jeff Power's there is a coal 4 feet 3 inches thick (13) which is believed to be the Upper Banner. This conclusion is based both on the stratigraphic position of the coal and on the presence in the upper part of the bed of a thin band of sandstone, which is a distinguished characteristic of the Upper Banner bed. It is reported that one-fourth of a mile southwest of Jeff Power's house the same coal is over 6 feet thick, but contains a parting of clay 1 foot thick (14). It seems from the evidence in the two sections that in one (13) the whole thickness of the bed is not exposed and more coal will be found in the floor.

In the yard at Sutherland's store, at Bucu, coal has been taken from the outcrop of a 32-inch bed (15) lying under shale; and close to the road on Left Fork one-third mile above Bucu there is an entry driven 35° W. on a 5-foot bed, another coal lying a little higher than the one just described, under heavy sandstone. The coal is in two benches separated by 10 inches of clay (16). The rocks seem to dip westward in this vicinity, and it is possible that the same coal has been opened one-fourth mile below Bucu in the east bank near Adolphus Kiser's store and on the opposite side of the stream at Z. T. Sutherland's.

An opening at Kiser's shows 3 feet 10 inches of coal with only one-half inch of parting (17). Twenty-five feet above it 20 inches of coal is exposed. On the opposite side of the creek the Sutherland opening shows a 5-foot 10-inch bed, which is peculiar in that the lower feet 3 inches is a mixture of clay and laminated coal standing on edge. From 10 to 15 inches below the roof there is a foot of bony, ashed, slickensided coal (18). This may be the Widow Kennedy bed.

One mile below Bucu there is an opening by the roadside now partly caved, which has a roof of sandy shale that shows conchoidal fracture. The coal is disturbed, being particularly curly in the lower

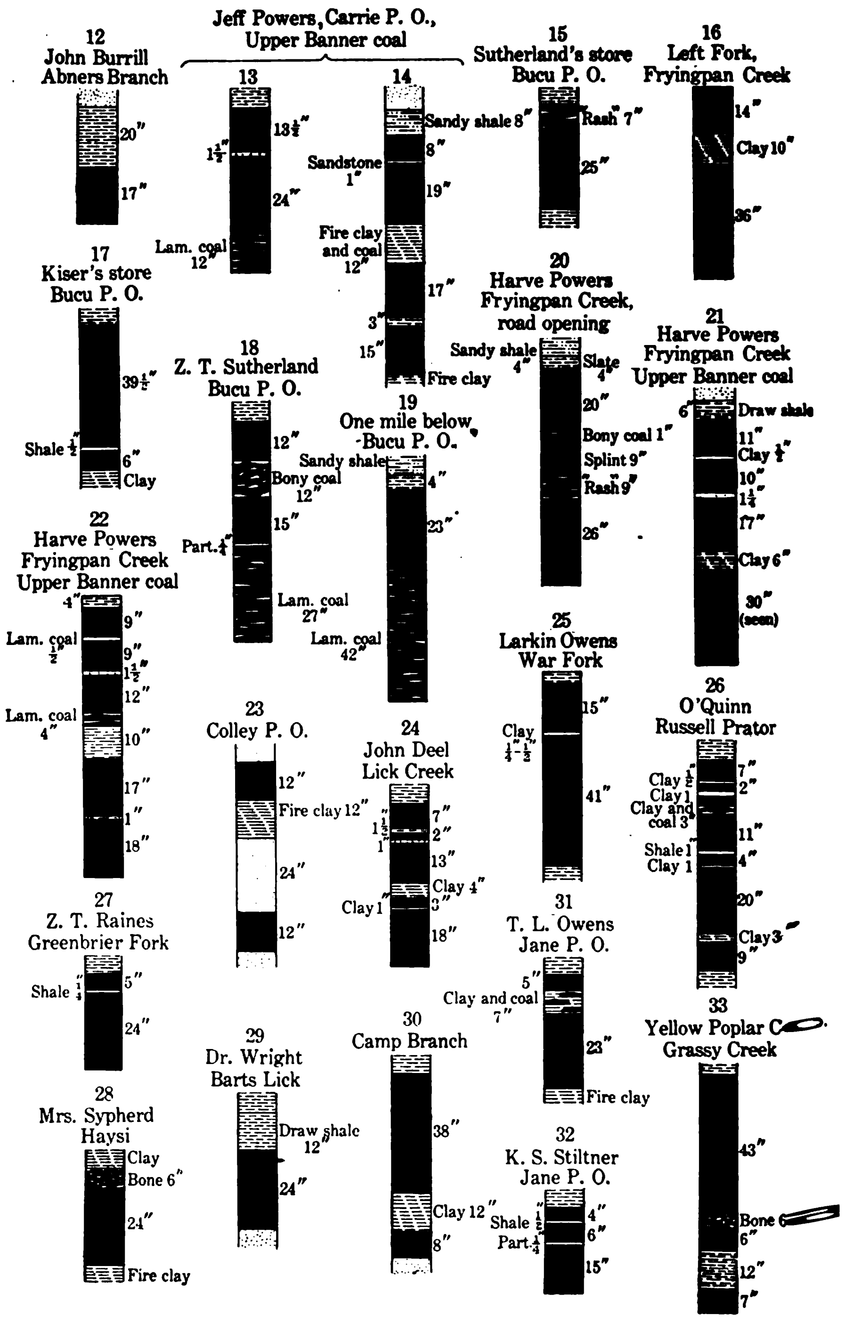


FIG. 17.—Coals on Russell Fork and its tributaries.

part of the bed, which is reported to be 5 feet 7 inches thick (19). Near Harve Power's, farther down the creek, another opening by the road is reported on the same bed and with the same thickness (20).

The Upper Banner coal has been opened in the head of the hollow back of Harve Power's, not far from Clement V. Rasnick's, on top of the ridge between Fryingpan and Lick creeks. It is 500 feet higher than the creek at Power's house. The coal is exposed in a 20-foot drift on the farther side of a spur 300 yards from W. G. Honaker's house. It is under a 50-foot ledge of sandstone and is over 6 feet thick (21). On the other side of the same branch a drift run 20 feet N. 80° W. down the dip shows the Upper Banner coal bed nearly 7 feet thick (22), according to a measurement by Mr. Hardaway. Less than 20 inches of the bed is clay or bone.

At the ford just below Colley there are two bands of coal 12 inches thick separated by 3 feet of sandstone and clay (23). The bed is of no value and is terminated at one end of this outcrop by a fault. There is 1 foot of coal in the road at the mouth of Priest Fork.

Lick Creek.—Coal exposures are few on Lick Creek. A 1-foot bed outcrops in the cliff one-fourth mile below the mouth of Dog Branch, and a pit on the left fork of Dog Branch one-half mile above Lick Creek near J. W. Self's house reveals a little coal. The shale roof at this point is regular and horizontal, but the coal is in irregular blocks or gobs mixed with contorted clay. Although the coal has been mined along the crop for 30 feet, no regular bedded coal was seen. The condition of the bed and its geologic relations suggest that this is the Widow Kennedy coal. An opening at creek level near the head of Beech Branch, at John Diel's, is on the Upper Banner coal. The bed is 4 feet thick (24) and has the characteristic sandstone parting.

Birchleaf.—A road opening on Russell Fork near Birchleaf, one-eighth mile south of Dicks Branch, is reported to have shown 4 feet of coal, and a short drift at T. K. Colley's at the mouth of Duty Branch shows about 4 feet of crushed and rolled coal under a roof of badly crushed or jointed sandstone. The roof is so treacherous that the pit is not kept open. Some of the coal has slickensided faces, and the whole appearance suggests the Widow Kennedy bed. The dip from the mouth of Fryingpan Creek to Dicks Branch is downstream.

Russell Prator Creek.—Russell Prator Creek, which enters Russell Fork opposite McClure Creek, is the largest of the eastern tributaries, but its coal resources have received little attention. There is a 1-foot bed in the road above Albert Owen's and a 15-inch bed one-fourth mile above Prator, on the left fork. C. C. Clevinger reports a bed 5 feet 10 inches thick in the top of the mountain 1 mile above the mouth of Greenbrier Fork. At the head of War Fork, 2½ miles above Prator, there is an opening in the hillside opposite and 130

feet above Larkin Owens's house and 100 feet below the top of the ridge. It has been driven 12 feet S. 70° E. up the rise and shows a bed (25) 4 feet 8 inches thick containing only one-half inch of clay. This coal is probably less than 200 feet above the creek at the mouth of War Fork and may be the Upper Banner. W. G. Raines reports that a 5-foot coal with no partings has been opened at the head of War Fork by Isaac Viers. This coal is caught only in the knobs on top of the ridge. A 3-foot bed of coal is reported near the head of the left fork above Prator.

On Greenbrier Fork of Russell Prator there are some small openings by the roadside a short distance above the mouth on a 15-inch and a 2-foot bed which are only 4 feet apart. On the east of Greenbrier, 2 miles above the mouth and 400 feet above the road, Albert and Wiley O'Quinn have recently run a drift about 20 feet in a southwesterly direction. The bed is over 5 feet thick, but has several thin partings (26).

An opening on Z. T. Raines's land at the head of Greenbrier Fork shows (27) 29 inches of coal, and two small openings on the same bed close to Joshua O'Quinn's house show about 2 feet of coal.

Haysi.—In the road a few rods west of the store at Haysi a 2-foot coal bed dipping north at an angle of 70° indicates a fold or fault at this point. The exposure is in front of a house occupied by Mr. Garrett on Mrs. Winnie Scyphers's land. In a ravine beyond the house, under a strongly jointed sandstone and between rocks standing vertical, there is an outcrop showing 15 inches of coal, 3 feet of fire clay, and at least 1 foot of coal below. The bed dips at a small angle and can be of no value on account of the greatly disturbed condition of the rocks.

At the head of the first west branch of Russell Fork above Pound River is a small excavation from which Mrs. Winnie Scyphers has taken a little coal. Six inches of bone and 2 feet of coal (28) compose the bed which dips strongly toward the northwest. One going from Haysi finds this opening in the first field on the right of the road, beyond the woods north of Mount Olive church. Along this road to the mouth of Pound River several coal blooms are seen, and one striking N. 20° W. crosses the road with a vertical dip.

Barts Lick.—On the road from the mouth of McClure Creek to Jane, on Hunts Creek, a coal bloom is exposed in the gap at the top of the ridge between Russell Prator Creek and Barts Lick, and at three points within 150 feet below the gap on the north side of the ridge. At the foot of the steep grade in the bed of the run tributary to Barts Lick a small amount of coal has been obtained by stripping a 1-foot bed in the road. One mile up Barts Lick from where the road going north leaves the main stream a 2-foot coal bed (29) occurs at the mouth of the first right hollow below the splash dam, in a pit

feet above the branch and 300 yards below Dr. J. W. Wright's house. It also shows in the bed of the branch close to the house. In 1906 coal was being mined at this place for use in a sawmill. At the crook of the road on the right fork of Camp Branch there is an opening on a coal bed nearly 5 feet thick (30) which has a 12-inch clay parting. The dip is strong to the east. This coal is not over 100 feet above the Lee conglomerate which shows in the branch below the forks, and may possibly be the Tiller coal.

Grassy Creek.—On Hunts Creek, the main fork of Grassy Creek, there is an opening by the roadside 2 miles above Jane, on the road to Grundy, which shows 2 feet 10 inches of coal with a shale roof and sandstone floor. A drift has been driven 15 feet down the dip which is toward the southeast. Half a mile farther the same coal has been opened in two places close together. These are caved now, but appear to have exposed between 2 and 3 feet of coal. On the south of Hunts Creek, one-half mile below the gap leading to Bull Creek, there is a timbered opening on the Yellow Poplar Company's land driven south 10 feet which shows 4 feet 1 inch of coal with one-half inch of clay 5 inches from the top of the bed. This opening is directly across the creek from a rocky ledge in the road. In a sag close to this ledge and 30 feet above the road this coal was opened once, but is now concealed.

On the branch which joins Hunts Creek from the east at Jane three openings were seen. The first of these is about one-third mile above Jane, in the hill on the left of the creek back of Tom L. Owens's house. It is 200 feet above the creek and is being worked by a drift which has been driven north 20 feet. The bed (31) is 2 feet 11 inches thick and contains a 7-inch clay parting. On the same side of the creek 1¼ miles from Jane, on the K. Silas Stiltner farm, there is an opening back of the house and 50 feet above the creek showing a 2-foot bed of coal with two thin partings (32).

About 1 mile above Jane, on Noah Mullins's land, there is a pit in a hollow on the south from which coal is taken every winter. It has been driven 30 feet in a southwest direction and shows from 28 to 30 inches of coal with shale roof and fire-clay floor. On the east of Abes Fork of Grassy Creek, in Old House Branch, the Yellow Poplar Company made three openings on a bed 1,270 feet above sea level. At one opening the bed is 4 feet 2 inches thick with a 7-inch clay band near the bottom, and at another it is reported to be 5 feet thick with the same clay parting. An opening on the left of Old House Branch shows the same bed over 6 feet thick (33) at the face of the drift, which is 1 foot more than at the outcrop. These openings are very close to the Pine Mountain fault and within a few rods of the State line.

M'CLURE CREEK.

McClure Creek heads against Sandy Ridge between Carrie and Fuller Gap, and flows north and east to join Russell Fork 3 miles above the mouth of Pound River. The occurrence of coal prospects in this basin will be described in geographic order from the head of the creek to the mouth.

Trammel Creek.—At the head of Trammel Creek a drift driven 20 feet S. 15° E. at the bend of the road 275 feet below Trammel Gap, on the Brooks farm, shows the Upper Banner coal (34) 4 feet 11 inches thick. The sandstone parting is 21 inches below the roof and is practically the only part of the bed that is waste material. The section is the same in the mine of the Clinchfield Coal Corporation at the head of Lick Creek on the other side of the ridge. This mine, known as No. 3, is situated on a tract of land lying under Low Gap and eventually it may be extended through to the north side of the ridge for natural drainage.

The Lower Banner coal has been opened in Trammel Creek, on Laban Phillips's place, to get coal for a steam engine used in diamond drilling. The drift extends a distance of 30 feet S. 20° E. and shows 4 feet of coal underlain by 3 inches of clay and 4 inches of bone. In the Clinchfield mine No. 2 at Dante on the other side of the ridge the average thickness of the Lower Banner coal is about 3½ feet.

A pit opposite the schoolhouse near the mouth of Trammel Creek shows the Widow Kennedy coal 7 feet thick, but decreasing rapidly with depth. A diamond-drill hole 150 feet away showed only 1 foot of coal at this horizon.

Homade.—Back of the post-office and store at Homade on the head of McClure Creek Reuben Owens has faced up a coal bed, which probably is the Lower Banner. The northwest dip makes the bed lower here than on the south side of Sandy Ridge. Nearly 4 feet of solid coal was visible, but the floor was hidden so that the whole bed was not measured (35). A small coal seen in the road farther upstream, and 100 feet higher than this exposure, is also believed to be the Lower Banner. Blooms of two other coals were seen higher in the ridge at 250 and 450 feet below the gap. The elevation of Flint Gap is approximately 2,750 feet, or 1,000 feet higher than the mouth of Trammel Creek. Trammel Gap is 2,533 feet above sea level.

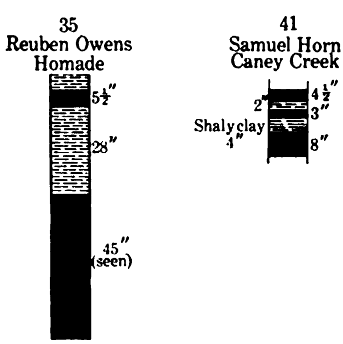


FIG. 18.—Lower Banner coal on McClure Creek.

The Widow Kennedy coal was once opened in the north hillside at the mouth of Roaring Fork 50 feet above water, but the pit is caved

and nothing was learned of the character of the bed. No openings were seen between Roaring Fork and Open Fork.

Open Fork.—The Grissell opening (36) at the head of Open Fork and on the opposite side of Sandy Ridge from Big Laurel Branch of Lick Creek shows the Upper Banner coal nearly 7 feet thick. Four feet of this bed is good available coal, leaving 8 inches of fire clay and 11 inches of coal in the floor, and 3 inches of coal over 7 inches of shale in the roof.

The Milton Carico opening (37) on the Upper Banner at the head of Middle Fork shows the bed divided by the same partings as at Grissell's, but the total thickness of the bed is less. At the outcrop it measures 6 feet 3 inches and at the face of the drift 6 feet 5 inches. The graphic section was measured by Mr. Hardaway at the face. An opening three-fourths mile above this, on the right of the stream, shows the Upper Banner less than 5 feet thick, but there is less waste in the bed.

An opening (38) on Coon Branch of Open Fork at Rasnick's, according to Mr. Hardaway, shows the Upper Banner coal over 9 feet thick, but containing a 35-inch clay and shale bed 41 inches from the floor. The Lower Banner, exposed near Mr. Rasnick's house, is 6 feet thick, but has 2½ feet of fire clay in the middle of the bed. The Widow Kennedy coal is reported from 3 to 5 feet thick near the mouth of Middle Fork. At Rasnick mill, on McClure Creek below the mouth of Open Fork, there are three openings on the Widow Kennedy coal about 75 feet above the road. The bed is in the midst of heavy sandstone and is 6 feet thick, but is so badly mashed and distorted as to be of questionable value. Jointing is conspicuous in the roof sandstone.

Caney Creek.—At the head of Caney Creek, close under Gibson Gap, the Upper Banner coal has been prospected by a drift 100 feet long at Alec Odle's. The bed at the outcrop (39) is 8 feet thick and at the face of the drift (39 a) 8 feet 10 inches thick. It contains a number of very thin partings. On Samuel Horn's land, on Hornspring Branch, the Upper Banner carries the same number of thin partings and is 7 feet 5 inches thick (40). At a distance of 50 feet this bed shows 3 partings aggregating nearly 2 feet in thickness (40 a). The Lower Banner (?) coal as seen in the stream bank at the mouth of Hornspring Branch (41) is 21 inches thick. These sections on Caney Creek were kindly furnished by Mr. Hardaway. Probably other openings have been made on this creek, for coal is reported on Rock House Branch, but none was seen.

On McClure Creek 1 mile above the mouth of Caney Creek 25 inches of coal is exposed in an old opening close to the road, and at George Dyer's, one-fourth mile above Caney Creek, there are two openings on the same bed, one of which is caved. An entry driven 40

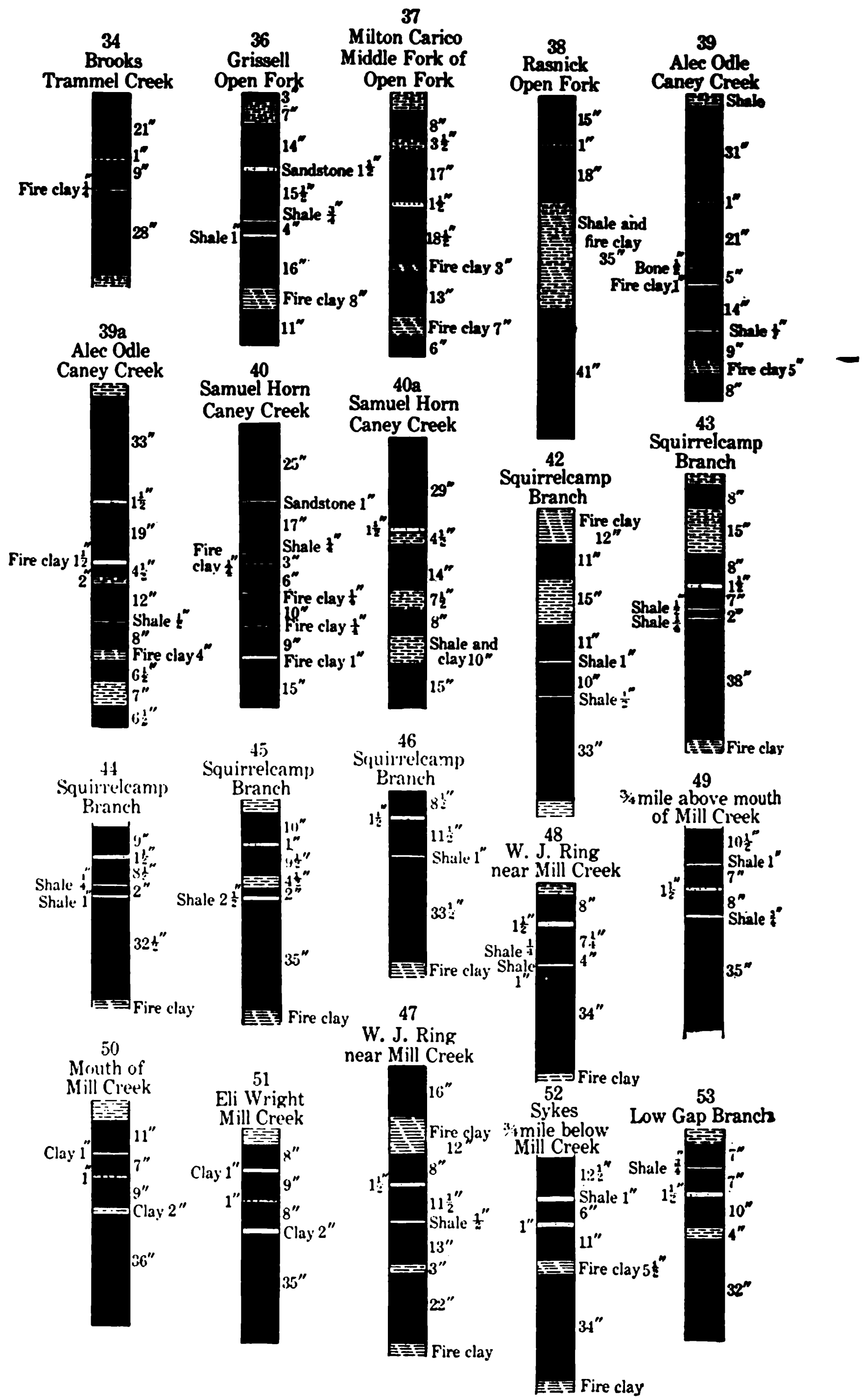


FIG. 19.—Upper Banner coal on McClure Creek.

›t down the dip is filled with water, and the thickness of the bed ıld not be determined, but it appeared to be about 5 feet. This ıy be the Widow Kennedy coal.

Squirrelcamp Branch.—Just below the forks of Squirrelcamp ·anch on the right of the stream, near a house, and 120 feet above e water, there is a 15-foot entry (42) on the Upper Banner al. The bed, which dips S. 35° E. at an angle of 6°, is 6 feet 9 ches thick, including 15 inches of shale near the top. On the right the left branch one-eighth mile above the forks the Upper Banner divided by the same number of small partings and one thick ıe (43), while on the left of the branch (44) the bed is in the me condition, except that the top bench of coal and the thick partg are wanting. At the head of Squirrelcamp Branch on the left the stream and 100 yards below a house the Upper Banner coal is feet 4 inches thick (45), and one-fourth mile below this on the ɔve Stanley tract on the right of the creek and just above the road measures 4 feet 8 inches (46). It is possible that prospecting in e roof will show another bench of coal here just as at the forks.

On the east of McClure Creek one-half mile below Squirrelcamp ranch at the lower end of the W. J. Ring tract the Upper Banner al is over 7 feet thick, a 16-inch bench of coal occurring in the roof 7). On the west of McClure Creek, opposite the first bend oneurth mile below Squirrelcamp Branch (48), this bed is 4 feet 8 ches thick. The section includes only 8 inches of coal above the ndstone parting. At the head of a hollow on the Ring tract there e two openings, in one of which the Upper Banner is 4 feet 10 ches and in the other 5 feet 5 inches thick. These sections resemble ry closely the measurements of the Upper Banner on Squirrelcamp ·anch.

Mill Creek.—In the vicinity of Mill Creek the Upper Banner coal s been prospected extensively and several sections have been tained showing the character of the bed in detail. Most of the ›asurements are by Mr. Hardaway.

On the northwest bank of McClure Creek three-fourths mile upeam from Mill Creek and 200 feet above water level the Upper nner is 5 feet 3 inches thick (49), with three thin partings. ı the opposite side of McClure Creek, at the bend 1 mile above ll Creek, there is another prospect, but the thickness of the coal s not learned.

An opening opposite the mouth of Mill Creek 190 feet above the ter (50) has been driven a distance of 30 feet N. 70° W. The l is 5 feet 7 inches thick and is divided by three partings aggregat- ; 4 inches. The Lower Banner should be about 75 feet below, but s not been opened.

The Upper Banner coal on House Fork of Mill Creek is 5 feet 8 to 10 inches thick, having the usual three thin partings found in this region, which aggregate less than 6 inches of waste. These features are shown by three openings, one at the head of the fork and two on the left of the stream.

On Toms Fork of Mill Creek the Upper Banner was measured by the writer in a 15-foot drift just above Eli Wright's place (51). The coal is under a 40-foot sandstone, is 5 feet 4 inches thick, and shows a persistence of the three thin partings in this vicinity. An opening opposite Wright's house, measured by Mr. Hardaway, duplicates this section within an inch or two.

A prospect on Sykes's land, one-fourth mile below Low Gap Branch on the east of McClure Creek, 260 feet above the water, shows the Upper Banner 6 feet thick (52). This coal has practically the same section on the Floyd Viers tract; the appearance of the bed is shown in Pl. VII, *A* (p. 92), from a photograph furnished by Mr. Hardaway. Two pits near the head of Low Gap Branch revealed the same bed 5 feet 2 inches thick. One of these pits (53) was driven 60 feet, and supplied coal to the neighborhood. So far as learned there are no coal openings on the lower 5 miles of McClure Creek.

CRANES NEST RIVER.

Extensive prospecting at the head of Cranes Nest River shows the character and position of the Upper Banner coal on Steele Fork and Trace Fork. The writer did not visit this section and the measurements are all by Mr. Hardaway.

Steele Fork.—On the west side of Steele Fork there are five openings, beginning one-half mile above the mouth, which show the Upper Banner varying from 1 foot 5 inches to 2 feet 7 inches in thickness. It seems likely that the bed is split and only the lower portion was found, for in an opening 1¼ miles from the mouth of the fork (54) the bed is 9 feet 4 inches thick, but carries 5 feet 9 inches of shale and clay in two partings.

At the head of Steele Fork the Upper Banner is exposed in three openings, having a lower bench of coal from 15 to 20 inches thick and an upper bench from 19 to 22 inches thick separated by 1 inch of sandstone. Three openings near Boatwright's house, which is on the west side of Steele Fork 2½ miles above the mouth, show (55) practically the same division and thickness of the bed, but openings one-half and 1 mile below Boatwright's show the bed with increased thickness due to the addition of several inches of carbonaceous shale and 9 inches of coal to the top of the bed (56).

Trace Fork.—Openings made at short distances from Fuller Gap to the mouth of Trace Fork show the character of the Upper Banner

coal. At the head of the creek, where the coal is at water level, the bed is 3 feet 2 inches thick and contains 1 inch of fire clay and 1½ inches of sandstone. At places a little farther downstream it measures 3 feet 4 inches, 3 feet 9 inches, and 4 feet, and in each place has 1 inch of sandstone 12 to 18 inches from the top. At John Lodge's house, which is 1¾ miles above the mouth of the fork, the Upper Banner coal is 35 inches thick on the right and 26 inches thick on the east of the creek (57). At Harrison Adkins's 27 inches is exposed and one-fourth mile farther downstream, on the east, the bed is 5 feet thick. In the latter place the increased thickness is due to the presence of a 21-inch seam of coal separated from the main

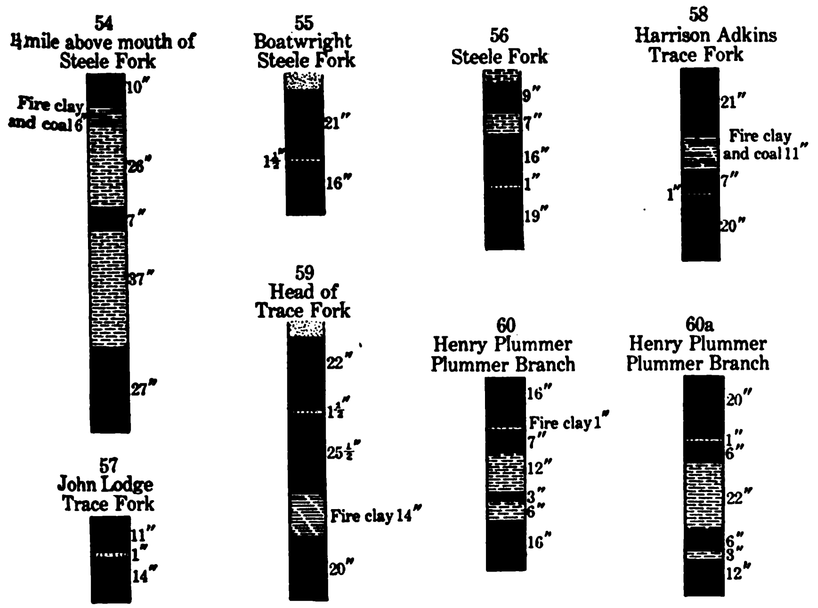


FIG. 20.—Upper Banner coal, head of Cranes Nest River.

bed by 11 inches of fire clay (58). Whether this is a local development or a case of more thorough prospecting is not known. It may be the former because in an opening reported to be up the hollow below the fan house of the Cranes Nest mine, on the head of Trace Fork, a bed measuring 7 feet 1 inch (59) diminishes to about 3 feet in a drift 300 feet long by the disappearance of the bottom fire clay and coal.

On the Wilson Adkins tract, one-fourth mile below the mouth of Steele Fork, an opening on the east of Cranes Nest River reveals 4 feet 5 inches of coal separated into two benches by 8 inches of fire clay. This is reported to be near the horizon of the Upper Banner, but it does not show the usual sandstone parting.

Birchfield Fork.—So far as learned there has been but little prospecting on Birchfield Fork. The only opening reported is on Henry Plummer's land in a hollow on the east of the fork 2 miles above the mouth. In this pit, according to measurements by Charles Addington, the thickness of the Upper Banner varies from 5 feet 1 inch (60) to 5 feet 10 inches (60a). The increase in thickness is due largely to a band of shale which swells from 12 to 22 inches. In the mine at Glamorgan, which is on the opposite side of the ridge from the head of Birchfield Fork, the bed averages 4 feet 4 inches thick and contains two very thin partings, but the writer did not have opportunity to attempt a correlation with any of the coals of Dickenson County.

Lick Fork.—About 2 miles above the mouth of Lick Fork and 40 feet higher than Jim Robinson's house a prospect (61) shows the Clintwood coal nearly 13 feet thick. In addition to the remarkable thickness, according to Mr. Hardaway, this bed is noteworthy for containing only 7 inches of shale or other partings. Isom Mullins opened this coal at the head of Lick Fork (62) and found the bed nearly 10 feet thick with 3 inches of partings. At the time it was visited in 1906 the opening was partly caved, and only 4 feet of coal was visible. In a field above this on the east of Lick Fork the bed is 10 feet 7 inches thick with 5 inches of shale in three partings (63). The prevailing dip is northwest.

Clintwood.—Carload samples of the Clintwood coal have been shipped from the Beverley opening (64) to test the coking quality. This opening is on Honeycamp Branch, a small tributary of Cranes Nest River south of Clintwood, and the coal is reported by H. W. Reitz to be 6 feet 9 inches thick without partings. At the head of Keel Branch prospects made by Henry Keel show this bed to be 10 feet 4 inches thick (65) in the opening at the edge of the woods and 8 feet 7 inches thick (66) at the field opening. An entry has been driven 100 feet, but the roof is weak and requires heavy timbering.

The John Lane opening, on Holly Creek one-half mile west of Clintwood, has an entry about 250 feet long, and shows 4 feet 6 inches of coal at the face. A combination of the upper part of the bed as seen at Lane's and the lower part as shown at Vanover's, on the opposite side of the creek, according to Mr. Hardaway, gives a total thickness (67) of 10 feet. It does not pay to remove the 20-inch fire clay to get the lower benches of coal. The same bed at the Joe Glenn opening, near by, is reported to be 6 feet thick with a 4-inch parting 13 inches above the floor. Two entries on the Clintwood coal just south of the village and 150 feet above Holly Creek are caved, and the sections were not obtained. The bed is said to be of the same thickness as at the Lane opening.

A considerable part of the coal used at Clintwood for domestic rposes is supplied by a small mine at the head of Long Branch ned by R. E. Chase and J. K. Damron. The opening is on the ntwood coal, which is above the Gladeville sandstone, and at this nt about 1,960 feet above tide. An entry has been driven over 150 t on a bed reported to be 6 feet 3 inches thick (68). Only the

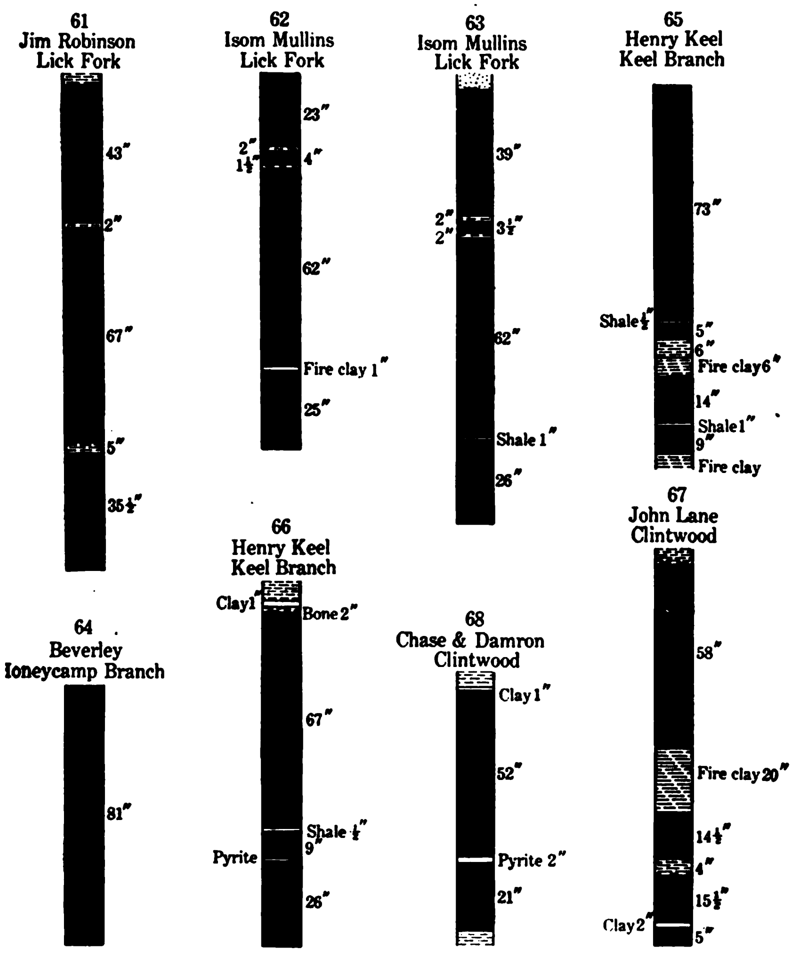


FIG. 21.—Clintwood coal on branches of Cranes Nest River.

per bench is mined. This is 4 feet 4 inches of solid coal. A sam- of this coal was taken by C. W. Dodge for analysis, and the result given in the table on page 119.

The Upper Banner coal has been opened at a number of points be- een Honeycamp Branch and the mouth of Cranes Nest River. On south of Cranes Nest, one-fourth mile above Keel Branch, on

Pres. Flemings's land, the bed is 5 feet 11 inches thick (69), with 10 inches of fire clay near the bottom, and one-fourth mile above this it is 5 feet 4 inches thick with 8 inches of shale near the top (70). Near the latter point the Lower Banner coal has a thickness of 3 feet 2 inches with a streak of shale in the middle (71).

At R. G. Baker's, above the mouth of Camp Creek, an opening 100 feet above the water shows at least 2 feet of coal (72). The bottom of the bed was hidden, so the entire thickness was not determined.

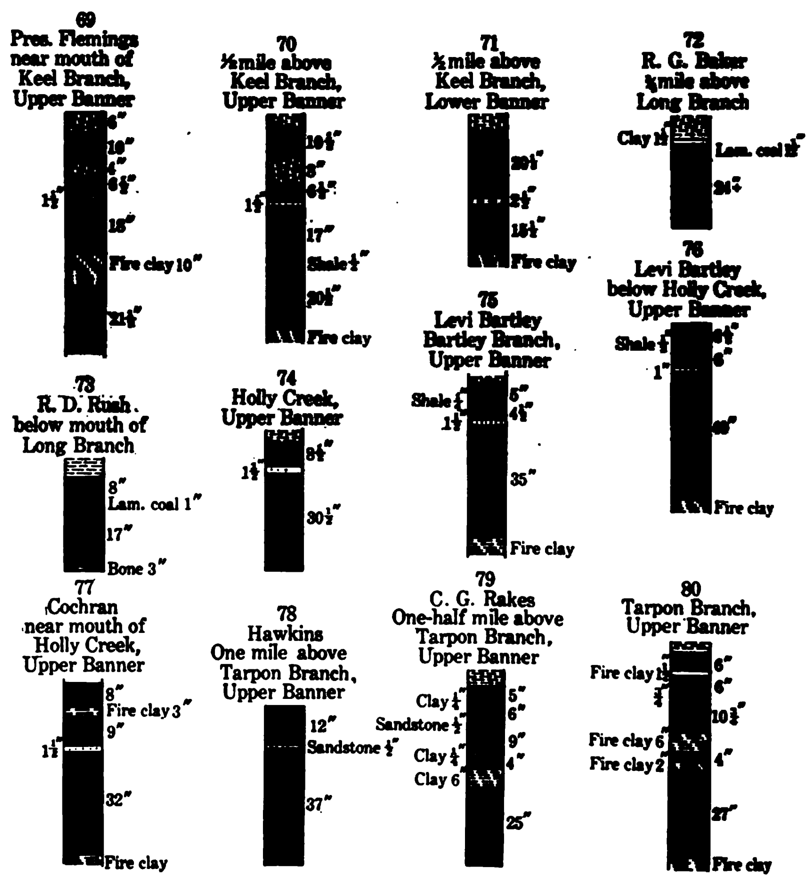


FIG. 22.—Coals on Cranes Nest River.

On the same side of the river below the mouth of Long Branch a bed (73) a little over 2 feet thick has been opened by R. D. Rush for domestic use.

The Upper Banner coal, according to Mr. Hardaway, has a thickness of 3 feet 4 inches (74) on Holly Creek, and 3 feet 10 inches (75) on Chase's land in Bartley Branch, which is the next branch below Holly on the same side of Cranes Nest River. Another opening

on the north of Cranes Nest above Levi Bartley's house, which is above the mouth of Bartley Branch, is said to show the Upper Banner coal 4 feet 6 inches thick (76), and an opening on the Cochran property, one-half mile above the last, shows 4 feet 5 inches (77).

Delaney's mill.—The Upper Banner coal has been prospected at a number of points near Delaney's mill on Cranes Nest River below Dwale. One of these, in a small watercourse close beside the trail which leaves the river about one-fourth mile above the mill, is under a sandstone ledge and has over 4 feet of coal (78) with only a thin sandy parting. Another is 180 feet above the river at C. G. Rakes's, the next house below Delaney's. This bed, as measured by the writer, is 4 feet 9 inches thick and has 8 inches of waste (79). Openings on Sugarcamp Branch opposite the mill and in the hill on the left of the river opposite Delaney's house have caved, but are reported to have shown the Upper Banner coal 4 feet thick with the usual thin sandstone parting and two or three one-fourth-inch shale bands. It is said to be 4 feet 1 inch thick on Honey Branch above J. F. Newberry's, and 5 feet 3 inches (80) at the head of Tarpon Branch one-half mile below Low Gap. At this point, according to Mr. Hardaway, there is an extra parting of 2 inches of fire clay 27 inches above the floor. No prospects were heard of below Tarpon Branch on Cranes Nest River.

The above notes show an average thickness of 4 feet for the Upper Banner coal on Cranes Nest River below Clintwood. It is a good mining proposition, because the coal is high grade and the amount of waste in partings is small. The bed is 100 to 300 feet above the river and has a gentle dip to the northwest.

POUND RIVER.

Pound River heads at Black Mountain and flows northeast 25 miles to join Russell Fork. Its course is parallel with Pine Mountain, but its length is greatly increased by loops and bends. Prospects for coal are more numerous on Indian Creek, Bowlecamp Creek, and Georges Fork than elsewhere on Pound River or its tributaries.

South Fork.—Reuben Bowling has taken coal from the bank of South Fork about 1½ miles below the source or one-fourth mile above the road to Flat Gap. The bed (81) is over 4 feet thick, but contains a 10-inch clay parting. Two drifts have been driven 25 feet S. 30° E. This bed is said to have been opened at one or two other places in the vicinity. Good coal is reported on C. F. Robinet's land, in the hollow below the road forks leading to Flat Gap, and an 18-inch coal is exposed in the road near the forks. On G. W. Hilton's land, at the mouth of Fox Gap Hollow, there is 28 inches of coal in a pit dug in the hillside across the road from his house. Coal blooms

were seen near Bond Mill and it is reported that 2 feet of coal has been found on John Stedman's land and was once stripped below the milldam.

Farther down South Fork a 2-foot bed of coal shows in the road, and in the creek bluff close under the road at the upper end of Thurston Banner's land there are two coal beds 10 or 15 feet apart. The lower one is almost at water level and shows 23 inches of coal, and

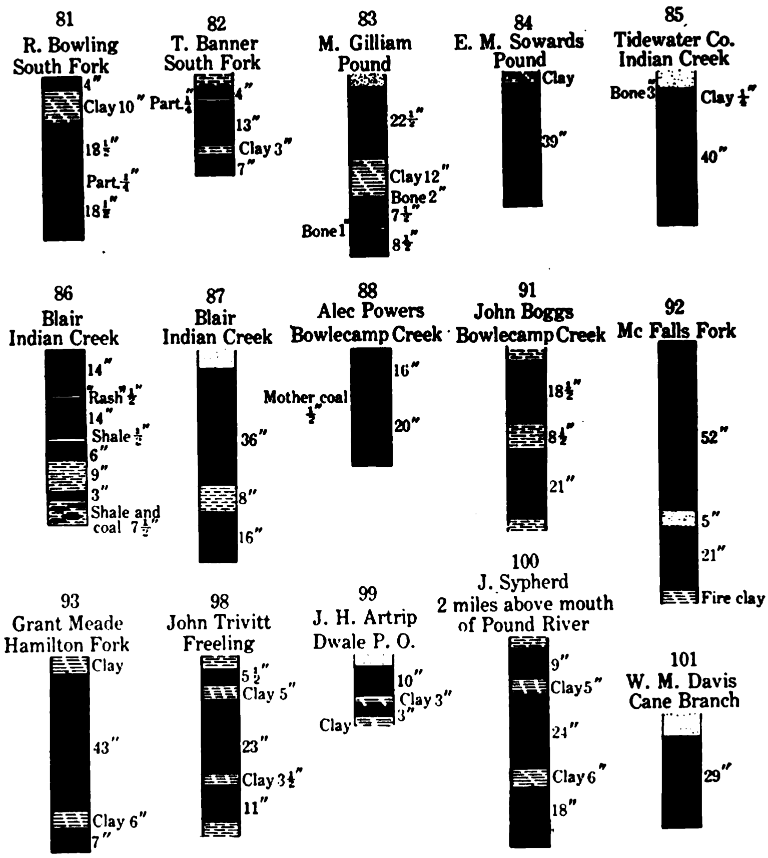


FIG. 23.—Coals on Pound River and its branches.

the upper one (82) is 2 feet 3 inches thick. Opposite Thurston Banner's house there is a prospect which, he reports, disclosed 23½ inches of coal. The coals from Bond Mill to Banner's rest on a massive sandstone and probably are the same bed.

At the mouth of Glady Fork a small pit dug by J. P. Qualls shows 3 feet of coal, the upper part soft and the lower part hard. This bed shows 2 feet 9 inches of coal in the river bank a short distance below the mouth of Glady Fork.

Several coal blooms are exposed in the road along the lower part of South Fork, but the only pits noted are on the land of Milburn Gilliam, above the road on the east of South Fork, about one-fourth mile from its mouth. Two old entries, one of which is said to be 150 feet long, are badly caved, and a third was opened in the autumn of 1906 to supply fuel for a locomotive operating on a lumber tramroad. The bed (83) is 4 feet 4 inches thick but contains a clay parting 1 foot thick. It has a fossiliferous shale roof.

North Fork.—Very little coal was seen on North Fork, and the chances of there being any worth much attention on the right or mountain side of the stream are small. It is reported that W. A. Bowling has a pit at Flat Gap on a 4-foot bed and that there is a 20-inch bed at George Adams's, 4 miles below Flat Gap. At Henry Short's, 1 mile above Meadow Branch, there is said to be a 2-foot bed of coal in the watercourse below the house, and a 4-foot bed is reported in the head of the hollow but it is not now exposed. In the hollow just below Meadow Branch and back of Josh Mullins's house a 12-inch and an 18-inch bed of coal are exposed in the shale bed of the branch. One is 30 feet above the other.

The only coal pit seen on North Fork is in the south bank opposite the Pound Gap road, or less than one-fourth mile above the forks. It is merely a small drain under a sandstone ledge where E. M. Sowards has dug a few tons of coal. The bed is 3 feet 3 inches thick (84) and the lower 2 feet is block coal. It is about 125 feet above the creek.

Coal blooms were seen in two or three places on the road from Pound to Pound Gap and a 1-foot coal is exposed on top of the Lee conglomerate about 500 feet below the gap.

Indian Creek.—Near the head of Indian Creek the bloom of a coal apparently about 2 feet thick is exposed in the road in two or three places. The bed dips downstream. There is also on the upper end of the creek and 100 feet above it an old entry now partly filled with water in which 3½ feet of coal (85) can be seen. The whole thickness of the bed was not learned. It dips S. 80° W. at an angle of 4°. Farther down the creek, 2 miles above the mouth, Mr. Hardaway reports a bed at water level and gives a measurement of 4 feet 6 inches (86), with the note that there is said to be 2 feet of coal below the visible portion of the bed. This is at J. H. Blair's, where a pit 25 feet above the creek is reported to have shown a 5-foot bed (87) containing an 8-inch parting. There is evidence of slight local folding of the rocks along this part of the creek.

An opening just above the Craft house, on the Chase tract, is said to have been driven 150 feet on a coal bed, the upper bench of which is 2 feet 9 inches thick. There is a coal bloom in the road above

the Tidewater Lumber Company dam, and at the mouth of Indi
Creek a 16-inch bed of coal shows beside the road 200 feet fro
Pound River.

Bowlecamp Creek.—At the head of the main fork, known as Dots
Fork or Baker Ford, a 3-foot bed of coal is reported below Al
Power's (88), and one-eighth mile farther downstream and at t
same elevation this bed is 3 feet 5 inches. On the George L. Bak
place, in the same locality, an opening has been made on a bed of co
over 10 feet thick (89) which has a close resemblance to the Clin
wood coal at the Lane and Keel openings (Pl. VIII, *A*). It is on t
of the Gladeville sandstone and 150 feet above a coal which shows

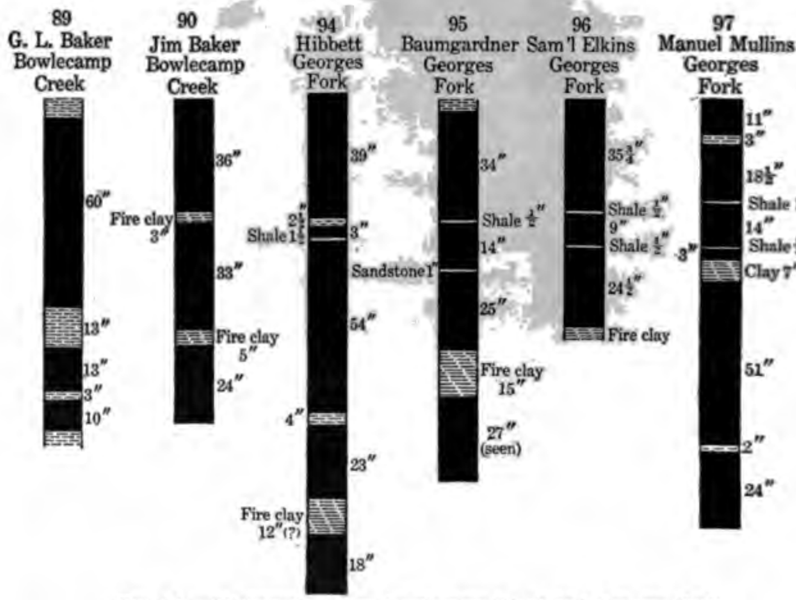
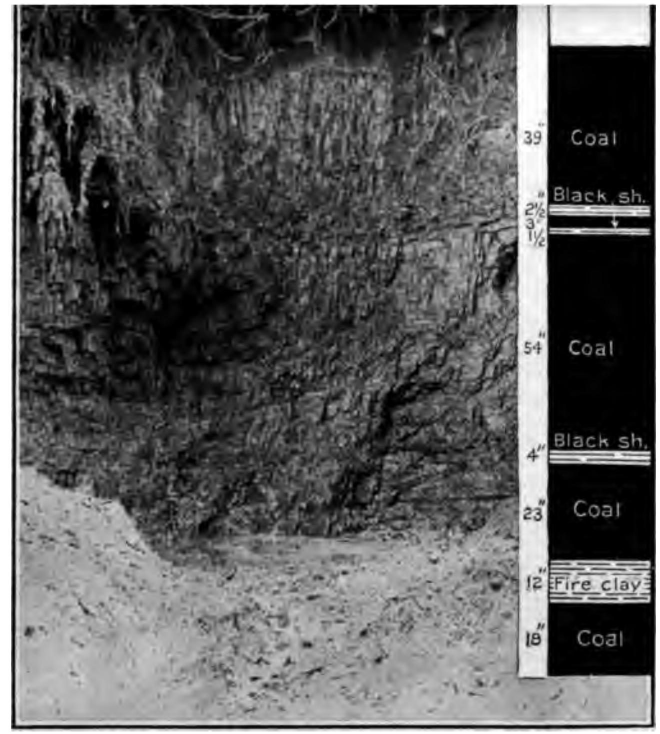


FIG. 24.—Clintwood coal on Bowlecamp Creek and Georges Fork.

a small bloom in the road. One hundred and seventy feet abo
Jim Baker's house (90) the same bed has thinner shale partings a
is 8 feet 6 inches thick.

A 4-foot coal (91) has been exposed on the John Boggs pla
on Mullins Fork of Bowlecamp Creek, and the same bed is report
on the main fork below Bud Hamilton's. In the bed of McFa
Fork, at an elevation of 300 feet above Pound River, there is a co
bed (92) reported to be 6 feet 6 inches thick. Near the head
Hamilton Fork, about 90 feet above the creek in a pit back of Gra
Meade's house, overlying a massive sandstone believed to be t
Gladeville, is the Clintwood coal bed, from 4 feet 8 inches to 5 fe
thick (93). A 4-foot 10-inch bed is reported 300 feet higher
the hill above the Meade opening on the land of Ira Mullins, a

A. TEN-FOOT COAL AT G. L. BAKER'S, BOWLECAMP CREEK.



B. HIBBETT OPENING, GEORGES FORK.

Photos loaned by H. Hardaway.

a bloom which may be this coal shows in the road about 70 feet below Georges Gap. At the head of Mill Creek, in a pasture one-fourth mile back from J. E. Alley's house, about 4 feet of coal is exposed in a surface pit. This bed lies on top of a conspicuous massive sandstone seen along the road below Alley's house and is probably the Clintwood coal. On the trail from the head of Mill Creek to the mouth of Bear Branch a 1-foot coal outcrops 200 feet above Pound River, and a similar bed occurs in a hollow back of Filmore Edington's on the west bank of Pound River between Bear and Whiteoak branches.

Georges Fork.—The Clintwood coal, described as 10 feet thick on Lick Fork of Cranes Nest River, has been prospected at a number of points at the head of Georges Fork and found to be over 8 feet thick under a considerable acreage. On the east of the creek, one-half mile below Georges Gap, on property of the Cranes Nest Coal and Coke Company, 4 feet of coal is exposed at the Hibbett prospect. The pit is partly caved and filled with water, however, so that the whole bed could not be seen. The thickness, according to Mr. Hardaway, is 13 feet 1 inch (94), of which only 20 inches is shale or fire clay (Pl. VIII, *B*). Three-fourths of a mile below this, on the left of Georges Fork, is the Baumgardner opening, in which the Clintwood coal is 9 feet 8 inches thick (95). An entry has been driven about 25 feet.

Two miles below the head of Georges Fork, in a hollow on the west side of the creek, an opening (96) on Samuel Elkin's land shows the Clintwood coal nearly 6 feet thick, and another prospect on the left of the creek belonging to Manuel Mullins (97) is reported over 11 feet thick with an aggregate of 14 inches of waste in 5 partings.

On Georges Fork, 1 mile above its mouth, in the rear of James C. Willis's house, there is a coal bed reported to be 2 feet 7 inches thick, with a 1-inch shale band near the bottom. The dip is strong downstream, and what is believed to be the same bed has been dug into by John Trivitt at water level one-fourth mile up the branch whose mouth is at Freeling. Two entries have been driven 20 feet on the coal, which is 4 feet (98) at this point.

Dwale.—Along the ridge road from Clintwood to the mouth of Cranes Nest River, coal blooms are exposed at a number of places. Two miles north of Clintwood, at a place where Campbell Willis is quarrying building and curbstone from the Gladeville sandstone, the bloom of a coal on top of the Gladeville can be seen, and the same bed, which is probably the Clintwood coal, should be found near the spring at the schoolhouse near Wood's store. Small coal blooms are common in the road at Dwale, and in a spring beside the road 30 feet below Nickels Gap, on J. H. Artrip's land, there is a 16-inch bed (99) containing a 3-inch clay parting.

Coal has been stripped from the bed of a small hollow on the land of W. J. Flemings, 1 mile northeast of Clintwood, but the thickness of the bed is not known. Two feet of coal could be seen above the water. This coal is immediately above the Gladeville sandstone, as is also a bloom seen 2½ miles northeast of Clintwood at Buddy Neal's and at Isom Flemings's, just over the divide, on the head of a branch which flows into Pound River. Isom Flemings has taken coal from the spring opposite his house, but has not uncovered the bed enough to determine its thickness.

Near the ford at W. R. Stone's, below Nickels Gap on Pound River, there is a 13-inch coal bed in the south bank close to water level, from which a small amount of coal has been taken.

East of Dwale and Nickels Gap there is a strong coal bloom in the road above Jim Scyphers's, which is said to mark the location of a 4-foot bed. In the ravine below Scypher's house a small pit in the woods (100) discloses a 5-foot 2-inch bed of coal which seems to be near the base of the Gladeville sandstone. The small coal last mentioned is in the bank of Pound River, just above the mouth of this ravine.

Cane Branch.—Along the road from Draten Musick's store to Mount Olive Church there are a number of small coal blooms, and at water level on Cane Branch, 200 feet below the point where the road crosses the creek, W. M. Davis has drifted 20 feet under a sandstone ledge on a bed of clean coal 2 feet 4 inches thick (101). The dip is northwest at this point.

Pine Mountain.—On the eastern flank of Pine Mountain and down to Pound River there are no important coal beds, for the reason that the greater part of the slope is composed of the Lee conglomerate. It is said that coal has been found at a number of points but not in abundance. The only exposure seen by the writer is a 20-inch bed about 60 feet below the top of the Lee conglomerate a few yards above where the road crosses Skeet Rock Branch. The beds here dip southeast at an angle of 25°.

EAST SIDE OF SANDY RIDGE.

There are three localities south of the area described in which active mining operations have been in progress for several years. These are Glamorgan, Toms Creek, and Dante. The coal mined at Glamorgan by the Stone Gap Colliery Company has an average thickness of 4 feet 4 inches, with only 2 inches of partings (102). It is known locally as the Glamorgan bed and has not yet been correlated with the coals on the north side of Sandy Ridge.

The Upper Banner coal is said to average over 8 feet thick in some of the mines on Toms Creek (103), but carries from 6 to 18 inches of fire clay and coal streaks a little below the middle. At Dante

(104) it is fairly free from partings and averages about 5 feet. The Lower Banner coal at Dante (105, 105 a, 105 b) has a thickness of about 3½ feet and varies considerably in short distances. In mine No. 1 at Dante the Widow Kennedy coal has an average thickness of 7 feet and in mine No. 4 on the opposite side of the creek scarcely 4 feet. It varies from 16 inches to 12 feet in thickness in mine No. 1.

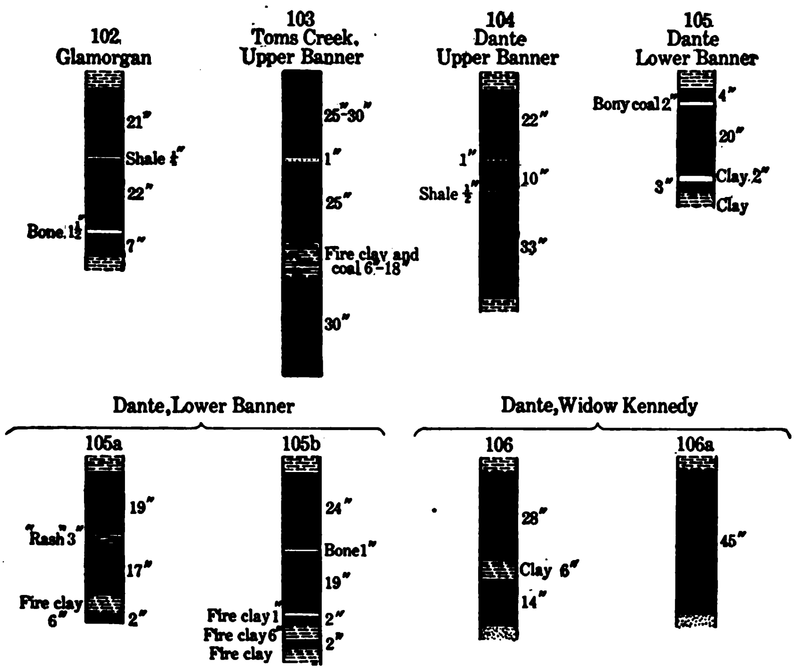


FIG. 25.—Coals on east side of Sandy Ridge.

Anything over 3 feet of clean coal is considered worth mining (106, 106 a). The coals at Dante have been described by the writer in a previous report.[a]

ANALYSES OF COALS.

The following 23 coal analyses are taken from private reports made by mining engineers and others to their clients and kindly furnished to the writer. They show the chemical character of the principal coals in the basin of Russell Fork in Virginia. The method of sampling is not stated. It is presumed that much of the moisture was lost by exposure to the air previous to analyzing.

[a] Stone, R. W., Coal Mining at Dante, Va.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 68–75.

Analyses of bituminous coals in Dickenson County, Va.

Opening.	Location.	Name of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	
Baumgardner	Georges Fork	Clintwood	[a]2.44	33.26	58.682	4.90	0.718	0.007	1
Beverley	Honeycamp Branch.	do	[a].62	33.63	60.951	3.95	.849	.01	1
Do	do	do	([b])	33.96	62.02	4.02	.77	-----	1
John Lane	Clintwood	do	[a].59	33.60	62.239	2.86	.711	.008	1
C. C. Kilgore	do	do	[a].55	32.11	60.721	6.01	.609	.005	1
Glenn	do	do	[c]1.12	29.80	65.156	3.20	.708	.016	2
Keel	do	do	[b].70	33.60	60.90	4.80	-----	-----	1
Keel, upper bench	do	do	[a].63	32.44	61.662	4.53	.738	.016	1
Do	do	do	[c].78	30.02	64.104	4.37	.707	.009	2
Keel, lower bench	do	do	[a].46	33.12	60.752	4.78	.888	.023	1
Do	do	do	[c]1.30	28.76	61.464	6.62	1.85	.016	2
Viers	McClure Creek	Upper Banner	[a].438	29.862	63.355	5.44	.905	.005	2
Sikes	do	do	1.05	33.99	60.70	4.26	.82	-----	1
Harden Branch	Fryingpan Creek	do	[d]1.56	28.62	61.35	8.47	-----	-----	2
Dawson mine	Dante	Lower Banner	.95	37.61	55.62	5.82	.82	-----	1
Caney Fork	Indian Creek	Tiller	[d].90	27.33	67.74	4.03	-----	-----	2
Barnett, upper bench	Duty	do	[a].304	25.436	64.594	8.88	.786	.021	2
Barnett, lower bench	do	do	[a].404	26.306	69.522	3.29	.478	.023	2
Taylor Sutherland	Bucu	Wid. Kennedy (?)	[d].95	23.36	61.43	14.26	-----	-----	2
Do	do	do. (?)	[a].428	23.022	63.735	12.15	.665	.013	2
Sutherland	do	do. (?)	[a].378	22.292	61.601	15.21	.519	.033	2
Dawson mine	Dante	do	.90	38.46	56.26	4.38	1.12	-----	1
Do	do	do	.85	35.25	58.14	5.76	1.13	-----	1

[a] Analyst, A. S. McCreath; sampled by James T. Gardiner.
[b] Analysts, Wuth and Stafford.
[c] Analyst, Otto Wuth; sampled by E. H. Steinman.
[d] Analyst, C. C. Tutwiler; sampled by Jansen Haines.

The above table contains analyses of three samples taken at Bu which are supposed to be from the Widow Kennedy bed. The ho zon of the bed at Bucu suggests this correlation, and the high pe centage of ash in the analyses indicates that the bed at that pla has suffered disturbance and is not an attractive mining propositic Three analyses are included from the Dawson mines at Dante. Da son is the former name of the mines now operated by the Clinchfie Coal Corporation, and these analyses are probably made of sampl taken from the same openings as those furnishing the coals who analyses are given in the second table below. Dante is just over t county line on the south side of Sandy Ridge, and these analys should represent the character of the beds in the adjoining portion Dickenson County.

An average of these 23 analyses gives a composite of the sever minable coals in Dickenson County, showing 29 per cent volati matter, 62 per cent fixed carbon, less than 1 per cent moisture, b tween 4 and 6 per cent ash, 0.831 per cent sulphur, and 0.015 per ce phosphorus. This average composition of the several beds of go coal is equivalent to that of the Pittsburg coking coal.

The averages of 11 analyses of Clintwood, 3 of Tiller, and 4 Upper Banner coal are as follows:

Average analyses of three coals.

Constituent.	Clintwood.	Tiller.	Upper Banner.
Moisture	0.92	0.536	1.03
Volatile matter	32.20	26.36	31.82
Fixed carbon	61.70	67.28	61.02
Ash	4.55	5.40	6.40
Sulphur	.855	.632	.708
Phosphorus	.012	.022	
Fuel ratio	1.91	2.55	1.95

The following table shows the results of analyses made at the United States Geological Survey's fuel-testing plant at St. Louis from samples taken during the prosecution of this work. The Clintwood coal was sampled by C. W. Dodge and the other three by the writer. Each sample was cut in the mine from a clean face of coal, including all binders or partings under one-fourth inch in thickness. It was crushed, quartered, and sealed air-tight in a can in the mine. By this method the moisture is retained until the sample is opened for analysis.

Analyses of Virginia coals.

[F. M. Stanton, analyst.]

	Name and location of coal bed.			
	Clintwood, Clintwood.	Upper Banner, Dante.	Lower Banner, Dante.	Widow Kennedy, Dante.
Laboratory number	3827	3942	4057	3947
Sample as received:				
Moisture	2.21	2.36	2.79	1.90
Volatile matter	30.13	32.40	32.11	31.54
Fixed carbon	63.68	57.92	59.30	60.87
Ash	3.98	7.32	5.80	5.69
Sulphur	.87	.66	.84	1.47
Calorific value: Calories				6,569
Calorific value: B. t. u.				11,824
Loss of moisture on air drying	1.20	1.30	1.80	.80
Air-dried sample:				
Moisture	1.02	1.07	1.01	1.11
Volatile matter	30.50	32.83	32.70	31.79
Fixed carbon	64.45	58.68	60.39	61.36
Ash	4.03	7.42	5.90	5.74
Sulphur	.89	.67	.85	1.48
Fuel ratio	2.11	1.79	1.85	1.93

The sample of the Clintwood coal was taken at the Chase & Damron mine near Clintwood and represents 4 feet 4 inches of a 6-foot 3-inch bed. It was cut at the face of the main entry, 100 feet from the outcrop. The sample of Upper Banner coal was taken in mine No. 3 of the Clinchfield Coal Corporation at Dante. It was cut from a clean face in butt entry No. 6 off the main gangway, where the bed is 5 feet thick. In mine No. 2 at Dante, at a point where the Lower Banner bed is nearly 4 feet thick, room 4 off the left entry, a sample

was taken of the 3 feet 3 inches of coal which is mined. The Widow Kennedy bed was sampled in mine No. 4, in the second cross heading, 300 yards from the entrance. A point was chosen where the coal is in its best condition and 3 feet 9 inches thick. It was solid and clean, rather than rolled, mashed, and dirty, as at many points in this mine.

The above analyses show that these coals are high-grade bituminous, comparatively low in ash, and have only a small percentage of sulphur.

In the following table are given average analyses of some well-known eastern bituminous coals, including the Elkhorn coals of the adjacent field in Kentucky and the averages of three of the best coals in Dickenson County.

Average analyses of eastern bituminous coals and of Russell Fork basin coals.

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
Pocahontas (average of 38) [a]	0.73	17.43	77.71	4.63	0.62	4.46
New River (Quinnemont) (average of 17) [b]	.60	19.93	75.20	4.27	.67	3.77
Tiller (average of 3)	.536	26.36	67.28	5.40	.855	2.55
Pittsburg (Connellsville) coking (average of 20) [c]	1.130	29.812	60.420	7.949	.689	2.03
Upper Banner (average of 4)	1.03	31.32	61.02	6.40	.798	1.95
Clintwood (average of 11)	.92	32.20	61.70	4.55	.855	1.91
Lower Elkhorn (average of 22) [d]	1.425	32.105	58.435	7.459	.574	1.82
Upper Elkhorn (average of 19) [d]	1.538	34.985	58.367	4.499	.587	1.67
Clinch Valley gas coal [e]	1.180	37.398	56.732	5.602	.619	1.52
Westmoreland gas coal [c]	1.427	37.521	54.921	5.418	.713	1.46
Pennsylvania gas coal [c]	1.280	38.105	54.383	5.440	.792	1.43

[a] White, I. C., Geol. Survey West Virginia, vol. 2, pp. 695, 696, 700.
[b] Ibid, p. 670.
[c] H. C. Frick Coke Company.
[d] Manufacturers' Record, vol. 45, No. 23, 1904, Supplement.
[e] McCreath and d'Invilliers, Mineral resources of upper Cumberland Valley, 1888, p. 145.

The sequence in this table is in accordance with the fuel ratio and shows the superiority of the coals in this field.

COKE.

The coals of this field duplicate in physical properties and chemical composition the coals on Toms Creek, Wise County, which make good coke, and it is believed that most of them will be found to be good coking coals.

Car samples of the Clintwood coal, taken from the Beverley opening on Honeycamp Branch and shipped to Chattanooga and Connellsville, made coke of the following character:

Analyses of Dickenson County coke.

	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.	Analysts.
72-hour	0.45	90.153	8.575	0.775	0.047	Wuth and Stafford.
48-hour	.031	91.224	7.695	.736	.035	Do.
72-hour	----------	90.91	8.34	.75	----------	Shomberger Steel Co.
	----------	92.03	7.22	.75	----------	Do.
48-hour	1.50	92.30	6.30	.69	.032	Do.
	1.03	92.76	4.373	.841	.026	P. D. Langdon.

To compare these results with analyses of Pocahontas and Connellsville cokes reference should be made to page 120 of this bulletin.

CORRELATION.

In view of the accuracy of the correlation work being carried on in the Appalachian coal field by David White, of the United States Geological Survey, by means of paleobotanic and stratigraphic evidence, the writer is not justified in attempting, on purely stratigraphic evidence, to correlate the coals of Dickenson County with those of the Elkhorn field on the other side of the Pine Mountain fault in Kentucky. It may be remarked, however, that the species of fossil plants from the Lower Elkhorn coal on Marrowbone Creek in the Elkhorn field bear a close resemblance to the plants from the Banner group of coals at Dorchester, near Norton, Va.

SUMMARY.

From the foregoing descriptions it will be seen that the area discussed contains a considerable amount of high-grade bituminous coal which is not yet being mined. On Indian Creek, at the head of Russell Fork, the Tiller coal bed has a thickness of 8 feet or more over an area sufficiently large to be worthy of consideration. Between Clintwood and Pound the Clintwood coal has been prospected at a number of points and found to be 8 to 10 feet thick. Throughout the McClure Creek basin the Upper Banner bed can be depended on to maintain an average thickness of 4 feet. Besides these there are other coal beds of minor thickness and unknown extent which will ultimately be of some value.

The coal in some and possibly in all of the beds of workable thickness will make excellent coke. Until railroads are built into this region, which is difficult of access on account of mountain barriers, the field will constitute a notable reserve of Virginia's coal resources.

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The following list of publications, in chronologic order, includes only such reports of the United States Geological Survey as describe the distribution and character of coals not far from Russell Fork. A complete list of Survey publications dealing with coal, coke, lignite, and peat is contained in Bulletin No. 316, pp. 518–532, and in Bulletin No. 341 (in preparation):

Production of coal. In Mineral Resources of the United States, 1883–1907.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

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The Southern Appalachian forest, by H. B. Ayres and W. W. Ashe. Paper No. 37, 1905, 291 pp. Describes the forested condition of southw Virginia, not including Russell Fork.

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Coal mining at Dante, Va., by R. W. Stone. In Bull. No. 316, 1907, pp.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 349

ECONOMIC GEOLOGY

OF THE

ENOVA QUADRANGLE

KENTUCKY, OHIO, AND WEST VIRGINIA

BY

WILLIAM CLIFTON PHALEN

WASHINGTON
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CONTENTS.

ILLUSTRATIONS.

ECONOMIC GEOLOGY OF THE KENOVA QUADRANGLE, KENTUCKY, OHIO, AND WEST VIRGINIA.

By William Clifton Phalen.

INTRODUCTION.

Importance of the area.—The Kenova quadrangle is of interest on account of its valuable deposits of coal and fire clay. Of less value are its iron ores, limestones, and building stones. It forms part of a much larger area in which during the last three or four decades there has been much activity in the mining of coal and in the mining and smelting of iron ores. The latter industry has been discontinued, but coal is still being mined. The clay industry in this region is small at present, but should have an important future on account of the amount of available raw material. (See Pl. I, in pocket.)

Location and area.—The Kenova quadrangle includes parts of Kentucky, Ohio, and West Virginia, the name Kenova being coined by combining abbreviations of these State names. Its exact position is shown on the accompanying key map (Pl. II). Far the greater part of its 938 square miles is within Kentucky, including the whole of Boyd County, the larger part of Lawrence, and parts of Carter, Greenup, and Elliott counties, Ky. A small part of Wayne County, W. Va., and the south end of Lawrence County, Ohio, make up the remainder. The quadrangle takes its name from a small town, Kenova, lying at the confluence of Big Sandy and Ohio rivers.

The portions of Kentucky and Ohio in this locality are sometimes known as the " Hanging Rock " region, from an outcrop of massive sandstone at Hanging Rock on Ohio River, a few miles below the city of Ashland.

From a geographic as well as a physiographic point of view, this area is a part of the western Appalachian Plateau province. It lies along the western edge and just north of the center of the great coal field comprised within this province, which extends from north-central Alabama to the southern boundary of New York.

Previous field work.—This area was studied by the geologists of the Kentucky Geological Survey during the latter half of the past

century. Most of the work on the coals and general geology in this particular area was done by Prof. A. R. Crandall. Mr. P. N. Moore examined more particularly the geology, distribution, and technology of the iron ores. Dr. I. C. White, director of the West Virginia Geological Survey, has measured sections in that part of the quadrangle which lies in Wayne County, W. Va., and the State Survey of Ohio has worked on the Ohio portion.

In addition to the work of these men special areas have been examined for private parties by geologists and mining engineers.

Literature.—The publications containing the most information on this area are the following:

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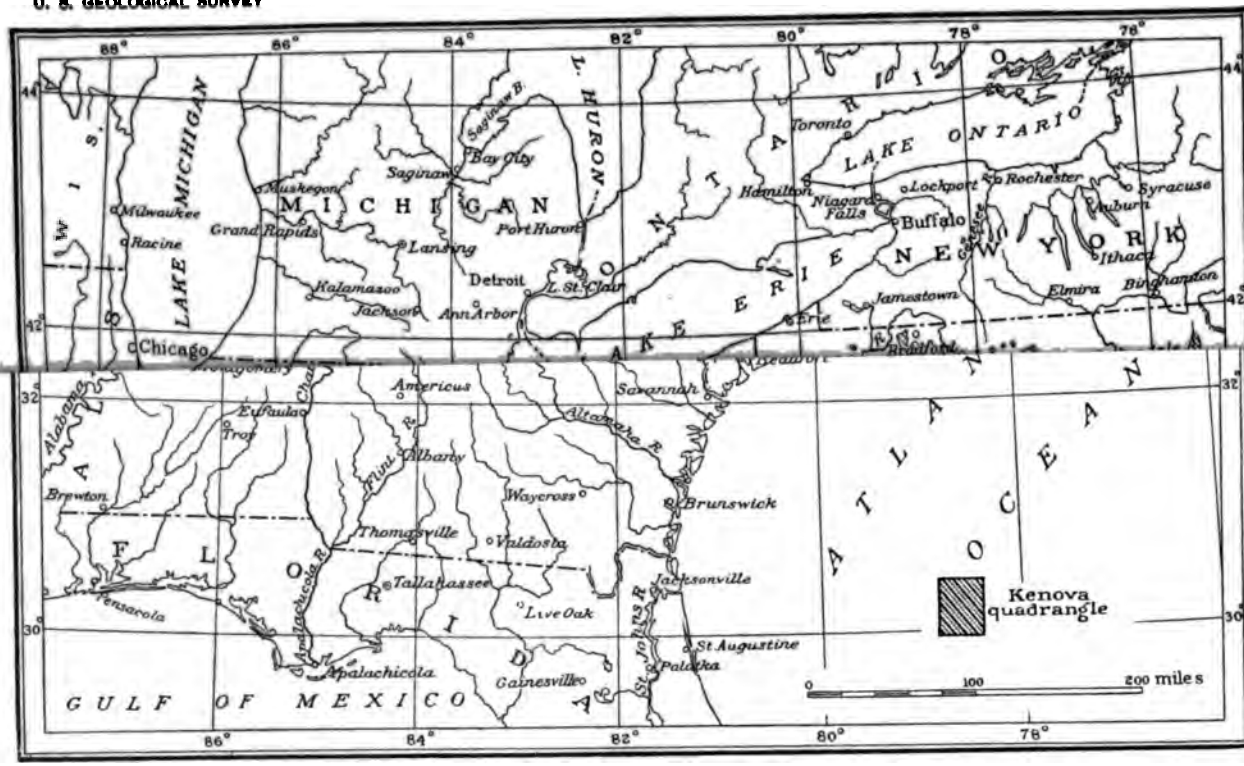
The reader will also get much information from the four volumes of reports of the first Kentucky Geological Survey, made by Dr. David Dale Owen in the years 1854 to 1860, inclusive. These early reports are somewhat discursive, and the information can most easily be found by reference to the indexes under the names of the various counties.

Present field work.—The field work on which this paper is based was done by W. C. Phalen in 1905, from the last of May to the first of November. George H. Ashley spent about two months in the field, visiting with the writer most of the critical areas and doing some independent mapping. David White also visited the field and spent somewhat less time making numerous careful and complete collections, which have furnished in part the basis for the separation of the formations chosen in geologic mapping. Numerous references to the work of Doctors Ashley and White will be found scattered through the text, and an expression of thanks is herewith extended to these geologists for courtesies both in the office and in the field.



KEY MAP SHOWING LOCATION OF KENOVA QUADRANGLE WITH REFERENCE TO THE ENTIRE APPALACHIAN COAL FIELD.

TOPOGRAPHY.

Relief.—The part of the Appalachian Plateau included in this region has been greatly dissected, until there is now scarcely any level land within the quadrangle, except the flood plains of the larger streams, like Ohio, Big Sandy, and Little Sandy rivers. This extensive erosion has resulted in sharp ridges, in many cases barely wide enough for wagon roads, and rather narrow valleys with small flood plains reaching well up to their heads. From the tops of the highest hills the remnants of the Appalachian Plateau may still be recognized in the even sky line (Pl. III, *A*). In a general way this ancient surface, or rather what remains of it, is highest at the south edge of the area, where the highest knobs reach an elevation of 1,200 feet. It slopes gradually northwest, and in the divide between the waters of Tygarts Creek and Little Sandy River only a few of the knobs rise above 1,000 feet. The lowest points in the area are those farthest downstream on Ohio and Little Sandy rivers and on Tygarts Creek. The flood plain of the Ohio ranges from about 530 feet above sea level where it leaves the quadrangle to about 560 feet where it enters it from the east. The flood plain of Big Sandy has an elevation of about 597 feet at the south edge of the quadrangle and 550 feet at the mouth of the stream, showing a gradient of about 1.1 feet per mile. This is slightly less than the gradient of Little Sandy. On Big Sandy the flood plain, though it may in places reach a mile in width, averages between one-half and three-quarters of a mile. The plain of Little Sandy from Grayson to Argillite has a greater average width, but in the upper portion of the river flood plains are wanting, the stream flowing through a gorge formed in the Sharon conglomerate.

The badly dissected character of the region has an important bearing on the exploitation of the natural resources. The railroads were confined during the early part of their history to the main river valleys and had to leave untouched for some time the more remote workable coal and clay beds; on the other hand, the flood plains, which are almost everywhere developed along the streams, are favorable to the construction of spur tracks that will materially lessen the haulage from mine breast to tipple.

Points of equal elevation are represented on the map by contour lines in buff, which are really the intersections of hypothetical plains with the surface of the country. These contour lines are placed 100 feet apart and, when carefully studied, enable the mind to grasp fairly well the general " lay of the land."

Drainage.—The drainage of this quadrangle is either directly or indirectly into Ohio River, which crosses its northeastern corner. The chief tributaries of Ohio River are Big and Little Sandy rivers

and Twelvepole and Tygarts creeks, the last named flowing across the extreme northwestern corner. Twelvepole Creek, entering from the Huntington quadrangle on the east, flows about 10 miles in a circuitous course in West Virginia and empties into Ohio River at Kellogg. Practically all the smaller streams flow into Big and Little Sandy rivers. Of these streams Big Blaine, a tributary of Big Sandy with an estimated length of about 70 miles almost wholly included within this quadrangle, and East Fork of Little Sandy are the most important. The Big Sandy, which in conjunction with Ohio River is the main drainage course of the area, is formed by the confluence at Louisa of Levisa and Tug forks. After flowing northward for 27 miles, it empties into Ohio River at Catlettsburg. Levisa Fork is often called Big Sandy.

CULTURE.

Roads and farming.—Though from the farmer's point of view this area is rough, it is completely intersected by fairly good country roads, the construction of which is facilitated by the fairly soft character of the rocks. The roads of Boyd County are notably well kept.

Notwithstanding the comparatively rugged character of the country, it is under general cultivation. The flood plains of the streams, which are subject to periodical overflow, are on this account very fertile. Along the valleys of the larger streams some wheat is grown, but corn is the principal crop. In Carter County many of the hillsides are given to the cultivation of tobacco. These crops, with the usual garden truck, constitute the principal products of the soil. The timber resources of this area are of little or no importance. Most of the big timber was removed during the days of the old charcoal iron furnaces, which flourished during the seventies and early eighties.

Railroads.—Most of the railroads are confined to the larger stream valleys. The main line of the Chesapeake and Ohio Railway enters the area from Huntington, W. Va., and crosses Big Sandy River at Hampton, keeping along the south bank of Ohio River. The Big Sandy division of this line, formerly known as the Chatteroi Railroad, follows the west bank of Big Sandy River. During the summer of 1905 the old wooden railroad bridges were being replaced by substantial stone culverts, curves were being straightened, and general improvements were under way in preparation for an expected increase in the freight traffic from the Elkhorn and other coal areas near the headwaters of Levisa Fork. The Louisville and Lexington division of this railroad crosses the area diagonally from northeast to southwest, leaving the main line at Ashland. The coal mined at Straight Creek, Grant, Rush, Princess, and Winslow is carried by

this line or by the Ashland Coal and Iron Railway, which is that portion of it between Rush and Ashland. The Norfolk and Western Railway has recently built a line down the eastern bank of Big Sandy connecting with its Twelvepole division and crossing Ohio River at Kenova. The new line is so much superior to the old in grade and general character that much of the coal from the headwaters of Tug Fork is now hauled over the new division. The Baltimore and Ohio Railroad has a terminus at Kenova. The Eastern Kentucky Railway, a short line constructed several years ago, has its southern terminus at Webbville, Lawrence County, and its northern terminus at Riverton, Greenup County, where it joins the Chesapeake and Ohio Railway. It carries staves, ties, etc., from the Blaine country and coal from its mines at Partloe, Boghead, and Hunnewell, as well as clay from the mines at Willard.

Locks and dams.—Big Sandy River has been under improvement by the United States Government since 1878. The plan of improvement adopted by Congress in March, 1899, contemplates carrying slack water as far as Pikeville on Levisa Fork, and to the mouth of Pond Creek on Tug Fork by the construction of 22 locks and dams. Within the limits of the Kenova quadrangle there have been built already three locks on Big Sandy below Louisa, one on Tug Fork at Saltpeter, and one on Levisa Fork at Chapman. By the aid of the dams the river will be navigable the whole year, instead of only about eight months, and the present commerce, chiefly in saw logs, cross-ties, staves, etc., will be largely augmented as a result of the cheaper water transportation. The development of the thinner coals within the Kenova area and in larger measure the thicker beds near the headwaters of the river will be aided. The navigable season of the smaller streams is so short that it will probably not aid materially in the development of the mineral wealth of this area. These streams are used chiefly in transporting logs and ties.

GENERAL GEOLOGY OF SURFACE ROCKS.

STRATIGRAPHY.

INTRODUCTORY STATEMENT.

All the rocks appearing at the surface within the limits of this quadrangle, with but a single exception, are of sedimentary origin and were laid down in or by water. They consist of sandstones, shales, limestones, coal beds, and iron-ore deposits, and have a total thickness of between 1,100 and 1,200 feet. All of these sedimentary rocks belong to the Carboniferous system, except the imperfectly consolidated gravels of the river terraces, which are of Pleistocene age, and the alluvium of the flood plains. The subdivision of the Carboniferous in the northwest portion of the Appalachian coal field,

which was proposed by Henry D. Rogers in the reports of the First Geological Survey of Pennsylvania,[a] has been accepted and followed, at least in its main features, by all the geologists who have subsequently worked in the territory to which this subdivision applies. The coal-bearing rocks have been followed from Pennsylvania into Ohio, and then southward in Ohio to Jackson County, and from this county into Scioto and Gallia counties, and through them into and across Lawrence County to Ohio River. Thus the stratigraphy of the "Coal Measures" of western Pennsylvania is brought into the northeastern corner of the Kenova quadrangle. The Carboniferous system, as developed in this quadrangle, consists of parts of the Pennsylvania and Mississippian series. The former contains the workable coals of this area. The rocks will be described in descending order, beginning with the youngest.

SEDIMENTARY ROCKS.

QUATERNARY SYSTEM.

Recent deposits.—The alluvium of the streams of this area is the youngest bedded deposit and has considerable commercial importance. It makes up the flood plains of both the large and the small streams, extending well up to their heads. The larger streams, like Ohio, Big Sandy and Little Sandy rivers, have deposits of this material fully 50 feet thick. Along Ohio River the width of this flood-plain deposit ranges from three-fourths of a mile to a mile, but on Big Sandy and Little Sandy rivers these deposits are not quite so wide. The material is being constantly cut out and redeposited by variations in the currents at each period of high water. The mode of utilization of these flood-plain deposits will be indicated in connection with the description of the clays (p. 120).

Pleistocene deposits.—None of this region lies within the glacial boundary, but there are deposits within the area which are considered of Pleistocene age. Just back of the city of Ashland is a district known as the Flatwoods, where the hills are flat and do not rise to an altitude of over 700 feet. These flat lands are covered with deposits of sand, gravel, quartz, and chert bowlders, some of which are 12 inches in diameter. These represent residual material from the remains of older crystalline rocks of the Blue Ridge to the east. This deposit may be traced fairly distinctly up Big Sandy River to the south of Louisa, maintaining its general elevation of about 150 feet above the present flood plain of the stream. These gravel deposits may, and do in places, represent the valleys of streams which long ago ceased to flow through them. The proof of this statement lies in the rounded character of the bowlders and in

[a] Vol. 2, pt. 1, 1858, p. 16 et seq.

A. OHIO TOPOGRAPHY, SHOWING LEVEL SKY LINE.

B. MAHONING SANDSTONE, LITTLE ICE CREEK, LAWRENCE COUNTY, OHIO.

certain topographic features usually associated with streams. Among the more conspicuous features of the remnants of these old, high-level valleys are their well-graded walls and the maturity indicated by their flat-bottomed floors. This floor in the Flatwoods area is nearly a mile wide. The old drainage channel represented by the Flatwoods is regarded by W. G. Tight[a] as a continuation of the preglacial Teays River.

Similar deposits have been found on the Little Sandy at elevations closely approximating those of the Big Sandy, and though the correlation of the two deposits has not been attempted, it is probable that the benches and their associated gravels on Little Sandy, when traced up Ohio River, will merge into those on Big Sandy. Silt associated with quartz pebbles has been discovered at lower elevations on Little Sandy, indicating a quiescent condition of the water with periods of deposition while these ancient streams were probably subsiding. Since these deposits, as developed in the Kenova quadrangle, have no economic significance, they will not be considered further.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

Monongahela formation.—The Monongahela in Pennsylvania was first termed the "Upper Productive Measures," since it marks an epoch in which several workable beds of coal were deposited. The base of the formation is marked by the Pittsburg coal. In accordance with Dr. I. C. White's correlation, the coal at the top of the hills east of Lett, near the mouth of Gragston Creek, West Virginia, is accepted for the time being as the Pittsburg coal and as marking the base of the Monongahela formation.[b] The area underlain by the coal does not exceed a few acres, and the formation is represented by 100 feet of shales with a massive sandstone at its base. No important coals are found in it except the Pittsburg bed.

Conemaugh formation.—The Conemaugh includes the rocks lying below the Pittsburg coal and above the Upper Freeport coal. What is regarded as the Upper Freeport coal with its overlying massive Mahoning sandstone is well exposed below Louisa in the vicinity of Zelda, and on Blaine Creek near Fallsburg. Above the sandstone which forms the roof of the Upper Freeport coal, and which varies in thickness from 20 to 30 or more feet, the rocks are in marked contrast with the rocks below, both in character and in the number and importance of the coal beds.[c] The massive sandstone is probably the

[a] Prof. Paper U. S. Geol. Survey No. 13, 1903. For a very complete description of Teays River to the east of this area see M. R. Campbell, Description of Huntington quadrangle; Geologic Atlas U. S., folio 69, U. S. Geol. Survey, 1900, pp. 2–3.

[b] West Virginia Geol. Survey, vol. 2, 1903, pp. 191–192. See also pp. 16–17 of this bulletin.

[c] Kentucky Geol. Survey, vol. C, 1884, p. 60.

same as that which overlies the Waterloo, Bayleys Run, No. 7, or Upper Freeport coal of the Ohio geologists, and which makes such a striking appearance along the banks of Big Sandy River near its mouth. The coal at its base in Lawrence County, Ohio, is regarded by the geologists of that State as higher than the Hatcher or No. 8 coal of the Kentucky reports.[a]

The position of the coal under consideration, which north of Louisa is immediately below a massive sandstone, the Mahoning of Owen, is strong evidence that it corresponds more probably with the coal above the Hatcher bed. Crandall, however, in his report on the geology of Greenup, Carter, and Boyd counties, explicitly states that coal No. 8 of the Kentucky survey is the first coal below the Mahoning sandstone of Owen, and follows the statement with the words that this coal is commonly known as the Hatcher seam.[b] In another place[c] he states that above the shales containing coals Nos. 7 and 8 occurs a coarse ferruginous sandstone, the Mahoning of Owen and Lesquereux. In this sandstone and its overlying rocks are found coals Nos. 9, 10, 11, 12, etc. However, J. J. Stevenson, in his description of the Allegheny formation in Kentucky,[d] interprets Crandall's generalized section of Greenup, Boyd, and Carter counties as placing coal bed No. 9 below the Mahoning sandstone.

In view of the evidence outlined above, the coal which has been opened below the massive sandstone exposed near Zelda and Fallsburg is regarded as the Upper Freeport and as the first bed above the Hatcher coal or No. 8 of the Kentucky reports. Normally, therefore, it would be No. 9 of the Kentucky series, and instead of coming within the Mahoning sandstone would occur just below it, as in Pennsylvania.

The minimum thickness of the Conemaugh formation is between 300 and 400 feet. It is almost entirely exposed only in a small area near the center of the basin in the hills east of Lett, W. Va. This may be due to a possible local thinning of the formation, for at other points near the center of the basin, west of Big Sandy River, where the hills rise as high, nothing is apparently known of the existence of the Pittsburg coal. If the thickness of the Conemaugh formation, 300 to 400 feet, obtained under the assumption that the coal in the hilltops near the mouth of Gragston Creek, West Virginia, is the Pittsburg bed, is compared with the thickness of that formation at Charleston and Huntington given by I. C. White, some question may be raised as to the correctness of the identification of the Pittsburg bed. White makes the Conemaugh 800 feet thick at Charleston and

[a] See section by E. McMillan, Ohio Geol. Survey, vol. 5, 1884, p. 122.
[b] Kentucky Geol. Survey, vol. C, 1884, p. 24.
[c] Idem, pp. 9, 10.
[d] Bull. Geol. Soc. America, vol. 17, 1906, p. 128.

feet at Huntington. However, the correctness of his identifica-
ı of the Upper Freeport coal at Charleston has been questioned,
h David White and J. J. Stevenson placing the Upper Freeport
l above the black flint, thus reducing the thickness of the Cone-
ıgh formation to a little over 600 feet. G. H. Ashley has been
lined to reduce it to 530 feet or less. The section of the Cone-
ıgh formation obtained by the Ohio geologists in Lawrence
ınty, Ohio, is only 420 feet thick, suggesting a westward thinning
the formation, which is in full accordance with the westward
ıning known to take place in going from Pennsylvania across the
handle of West Virginia into Ohio. If the coal in the Kenova
drangle is the Pittsburg bed, the thickness of the Conemaugh is
ch less than it is to the northeast at Huntington and slightly less
n the Ohio geologists make it.

'he rocks of the Conemaugh are mainly red or greenish shales,
h beds of limestone and iron ore and in some localities important
s of sandstone. The fact that it contains no workable beds of
l, together with the sharply defined character of its rocks as con-
sted with those of the formations above and below, serve in part
ı basis for making it a separate formation. The members of the
nation in this area are generally irregular in their development,
are on this account poor guides in unraveling the stratigraphy.
basal member, however, which is the Mahoning sandstone, is very
sistent and hence a valuable guide in tracing this formation.
e Pl. III, *B*.) Above this sandstone at variable intervals occurs
ther persistent limestone, one of the Cambridge limestones, which
ısually capped by a cliff-making sandstone. These two massive
dstone members occurring near the base of the Conemaugh serve
learly demark it in most localities from the underlying rocks, the
e so because the succeeding higher rocks are usually red shale.
some parts of the quadrangle, notably near the mouth of Big
ıdy River, the basal sandstone is unusually thick and massive, at-
ıing near Kenova a thickness of 70 feet, and is continuous, with
a few irregular intercalations of shale, east to Ceredo, south of
ch it becomes even more massive and attains a thickness of 100
. Above this sandstone there is usually a small coal, which may
the Brush Creek coal of Pennsylvania. This is an unimportant
, though it has been worked in the hills opposite Louisa. It will
bably not be of any great commercial importance in the near
ıre. The Cambridge limestone overlying the Brush Creek coal is
ery persistent member and is a most valuable guide in tracing the
ks of the Conemaugh. In many places it consists of two members,
upper and a lower, as shown by the section obtained near the bed
Whites Creek, about 1 mile west of Potomac (p. 131).

In the western part of the quadrangle, near Willard, this limestone usually occurs as a single layer. At Willard it is found near the hill-tops 180 feet above coal No. 7, but the interval above this coal is in some places slightly less than that. This limestone has a very characteristic appearance, and, owing to the fact that it is highly siliceous, it withstands weathering, and can usually be found at its proper horizon. Almost directly above it occurs a small bed of coal, locally workable. Overlying this coal at a varying interval is a massive sandstone. The distance between the base of this sandstone and the limestone ranges from 10 to 40 feet, but averages about 35 feet. This sandstone is rarely more than 25 to 30 feet thick, but is usually massive and coarse grained, and makes prominent outcrops. Capping this sandstone is a mass of red shale, near the base of which occurs a small bed of coal. The remainder of the Conemaugh is prevailingly red and for the most part the rocks are shales or shaly sandstones with a few bands of massive sandstone. (See Pl. III, *B*.) The formation contains practically no workable coal.

Allegheny formation.—The Allegheny formation underlies the Conemaugh and is about 180 feet thick in the northern part of the quadrangle, but in places it varies considerably from this thickness, as in the southern part of the area, where the thickening of the Homewood sandstone seems to have interfered with the normal development of the Allegheny. The top of this formation is the top of the Zelda coal, which is believed to correspond to the first bed above the true Hatcher coal of Ohio, and hence to be the Upper Freeport coal of Ohio and normally No. 9 of the Kentucky series. The base of the formation is demarked from the underlying rocks both on paleontologic and lithologic grounds. It is the base of coal No. 5 of the Kentucky series, which according to Stevenson [a] corresponds to the Brookville coal of Pennsylvania. This coal lies practically at the top of a massive sandstone in the Kenova quadrangle, which is regarded as the equivalent of the Homewood sandstone at the top of the next lower (Pottsville) formation. In the western part of the quadrangle, though all the more constant members of the Allegheny are present, the formation seems to be thinner than in the region around Ohio River and to show considerable variation. On one side of the hill west of Willard it is about 130 feet thick, but on the other side it is less than 100 feet. It should be noted that in this district the Homewood sandstone thickens to 100 feet, and in general it may be said that throughout the area the Allegheny formation tends to become thin as the underlying Homewood sandstone thickens. This formation was known in Pennsylvania as the "Lower Productive Measures," from the fact that it is the lower of the two groups of rocks containing valuable coals. It also contains a valuable clay deposit in this part of

[a] Bull. Geol. Soc. America, vol. 17, 1906, p. 128.

Kentucky. In addition it contains beds of sandstone, shale, iron ore, ınd limestone. Unlike the formation on which it rests, it is, as a rule, ıot decidedly sandy, and the character of its fossil plants is so disinct from that of the plants in the Pottsville as to warrant its sepaation as an independent formation.

The number of coals present in the Allegheny formation is usually .ot more than six, and in many places not more than four. The lowst coal, No. 5 of the Kentucky Survey, lies directly on the Homewood andstone. It is locally of workable thickness.

An important member in this formation has been called the "Ferriferous" limestone by Andrews in the reports of the Ohio Geological Survey, and the "Hanging Rock" limestone by Orton.[a] It is the quivalent of the Vanport ("Ferriferous") limestone of western Pennsylvania, and that name will be used in this report.

Its relationships in the Kenova quadrangle may easily be made out t Coalgrove, opposite Ashland. (See section on pages 30–31.)

It usually lies from 10 to 20 feet above the top of the Homewood andstone, and is found at its top in many places where coal No. 5 s absent. It is generally associated with an important clay bed, and n this account has an economic interest. This clay ranges in thick.ess from 4 to 6 feet. The next higher economic member in this ormation is the No. 6 coal of the Kentucky section, known in the egion about Ashland as the "Limestone coal" and in Ohio as the Newcastle coal." It is commonly found 20 feet above the Vanport "Hanging Rock") limestone.

The next higher coal is the Coalton, or the No. 7 of the Kentucky Geological Survey, or the No. 6 or Sheridan coal of Ohio. This is the elebrated Nelsonville coal of the Hocking Valley. It is the most imortant bed in this area at present and is found from 25 to 45 feet bove coal No. 6 and from 40 to 50 feet below coal No. 8, the next igher bed in the formation. This coal No. 8 is workable in parts of ie quadrangle, but is as yet comparatively unimportant. From 40 › 50 feet higher in the scale is coal No. 9, which, like the coal below , is generally a thin bed and only locally workable.

Besides the coals and fire clays of economic importance in this ormation, various beds of iron ore occur. These formerly had conderable importance, but at present have little or no value, as the heaper ores of Lake Superior and Alabama have entirely replaced ıem in the market. The general sections (Pl. IV and fig. 20) show he beds of economic interest and the intervals between them.

Pottsville formation.—The Pottsville formation is the lowest in he Pennsylvanian series. Its base is the top of the Mississippian eries, on which it rests unconformably, and it comprises all the rocks

[a] Ohio Geol. Survey, vol. 3, pt. 1, 1878, pp. 885 et seq., 892 et seq.

to the top of the Homewood sandstone. This formation is separated from that lying below and from that above on both lithologic and fossil evidence. The entire formation is exposed in the northwestern part of the quadrangle, where it has a thickness of between 350 and 400 feet. In the southeastern part of the area it has a thickness of at least 600 feet, and along the southern edge it must be fully as thick. General sections showing the character of the rocks of this formation, as exposed at different points of the area, are given in Pl. IV. The rocks of this formation are decidedly sandy, but contain occasional beds of shale, iron ore, limestone, and coal. Owing to its thickening in the southeastern part of the area and the introduction of coal beds not represented in the section in the western part of the field, the lowest coals in the area are believed to appear in the section along Levisa Fork near Gallup. There are three or four of these beds, and the thickest of them is not over 2 feet at any point. The higher coals in this formation are all locally workable and have been numbered by Prof. A. R. Crandall (Pl. IV). There are usually four fairly thick coal beds in this formation, but at some points this number may be increased to five and even six. Detailed descriptions of these coals, together with the intervals which separate them, are given under the headings of the various districts.

The Pottsville formation also contains some very valuable beds of fire clay. Most noteworthy of all is the bed occurring only a few feet above the top of the Maxville limestone. This is the celebrated Sciotoville fire clay of Ohio. Though it outcrops over a very small area in this particular quadrangle, it has considerable economic importance to the west, and it is being mined at present on a large scale in the vicinity of Olive Hill. Other beds of fire clay in this formation are locally workable, notably the bed associated with coal No. 4, which has been worked in the eastern part of Ashland and on Catletts Creek. Nearly one-half of the entire surface of this quadrangle is covered by rocks belonging to the Pottsville.

MISSISSIPPIAN SERIES.

The Mississippian series is represented by a massive limestone, called in the Kentucky reports "Sub-Carboniferous limestone," and in those of Ohio the Maxville limestone. About 100 feet of the Waverly group is also present. The outcrops of the limestone are confined to the western part of the area and are limited in extent. West of Tygarts Creek, in Greenup County, this rock is present in the hills. Here it does not exceed a thickness of 25 feet, being underlain by 100 feet of sandstone and shale belonging to the Waverly. A small outcrop of limestone is found at the bend in Everman Creek, Carter County, just above the mouth of Wolfpen Branch, and again farther up the creek, just at the edge of the quadrangle. The lime-

ne in this part of the field does not exceed 15 or 20 feet in thick-s. It is usually overlain by a thin band of iron ore. This lime-ne is encountered in all the deeper borings for oil, in both the tern and western parts of the quadrangle, and reaches in places a ckness of several hundred feet. The total thickness of the Mis-sippian rocks outcropping in the western part of the area does not eed 150 feet.

IGNEOUS ROCKS.

Occurrence.—Igneous rocks in this quadrangle were noted by ofessor Crandall many years ago. They are found in the hills on h side of Ison Creek west of Stephens, Elliott County, and about miles southwest of Willard. The region was visited by J. S. ller, of the United States Geological Survey, in 1884, and as a ult of this trip a very detailed account of the occurrence and trography of these rocks was published.[a] The rock is peridotite, d owing to this fact is of more than usual interest, first, because it ars a resemblance to the peridotite of South Africa, the mother k of the diamond, in the Kimberley district; and second, owing to relative scarcity of this type of igneous rock and to a possible ationship to the mica peridotite of western Kentucky.[b] In an-er publication Mr. Diller has applied the name of kimberlite to s rock from its resemblance to the South African rock.[c]

Extent.—The area covered by the rock is very small, not more than few acres. The outcrops of the solid ledge are not numerous, but ir original extent is not difficult to trace, owing to the character-ic minerals resulting from weathering. There is no apparent rea-n why the various isolated masses should not be considered parts a single intrusion, as all appear identical in mineral composition.

Character of rock.—The groundmass of this rock is compact, gray-black in color, and porphyritic. It is plentifully specked with enocrysts of olivine, which appear to be very fresh and unaltered d give a grayish tinge to the rock. Garnet (pyrope) and titanic n ore (ilmenite) are also easily detected and in the field were found be of great assistance in tracing the boundaries of the decayed lges. Sections of biotite are not uncommon. Besides these con-tuents, which are readily detected in the hand specimens, the chief naining minerals are enstatite and a small amount of apatite. In ces the olivine has been altered to serpentine, which may be dily seen in hand specimens, and which in thin section is asso-ted with magnetite and some carbonate, presumably dolomite re-ting from the alteration of the olivine. This rock has been so roughly described by Diller, and its peculiar characteristics are

[a] Bull. U. S. Geol. Survey No. 38, 1887.

[b] Williams, G. H., Am. Jour. Sci., 3d ser., vol. 34, Aug., 1887, p. 137.

[c] Bull. U. S. Geol. Survey No. 150, 1898, pp. 290–294.

so well pointed out in his publication, that it will not be further considered here.

Age and relationships.—The sedimentary rocks through which the igneous rock has forced its way are traceable practically up to the contact and strangely enough do not appear to have been even flexed upward along this zone. Though the igneous rock has broken off masses of shale, which are now found embedded in it, this is surprisingly fresh and unaltered, like the ordinary black shale of the Pennsylvanian series. Only in a few cases are metamorphic effects markedly visible. In some of the baked shale secondary mica was seen in considerable quantity. The color of the shale had been somewhat reddened and the sandstone and limestone fragments, which were inclosed by the igneous rock, had been baked and the latter converted to quicklime.

The sedimentary rocks in which the bulk of the igneous rock is found belong to the Pottsville formation, but as some of the igneous rock is found in the Allegheny, the intrusion is Allegheny or post-Allegheny in age. It was forced into the carbonaceous shale and coal beds found in this formation, and, owing to the fact that the Kimberley diamonds occur in peridotite penetrating carbonaceous shale, more than ordinary interest attaches to the Elliott County occurrence of peridotite. This interest has led to the prospecting of streams in the neighborhood, and also to the sinking of a shaft 70 feet deep, which at the time of the writer's visit (October, 1905) was filled with débris. During the spring of 1906 it was reported that another prospect shaft was being sunk. As to the presence of diamonds the writer has no authentic information.

STRUCTURE.

MODE OF REPRESENTING STRUCTURE.

The inclination of the beds to a horizontal plane, or the dip of the beds, as it is commonly called, is measured in the field by means of a clinometer when the inclination is great enough to be susceptible to this method. In but few localities, however, in the Kenova quadrangle are the dips sufficient to allow this mode of measurement. Where this method is not applicable continuous road sections are run and the beds are correlated from hillside to hillside. When the elevation above mean sea level of a given sandstone, coal, or limestone on one hill and its elevation a mile or so away have been found, the rise or fall of this particular bed in feet per mile is at once obtained. By connecting points of equal elevation on any selected bed the contour lines for that bed are drawn. On the map, Pl. I, the contour interval is 50 feet and all points having altitudes

that are multiples of 50 were connected by black lines. For instance, in drawing the 600-foot contour line those points in the area where the datum selected (the top of the Homewood sandstone) reached this elevation were connected, and likewise for the other contour lines.

The top of the Homewood sandstone was selected in this area, on account of the ease with which this bed may be followed, owing to its persistence and relations to other well-known horizons. Where it failed to appear above drainage, its distance below other known beds was used, assuming, of course, that the distance was constant within the limited area where this means was employed. Conversely, when the dips were such as to carry the top of the Homewood above the hilltops its distance above known beds was applied. However, great precision was not obtainable, as such intervals are subject to variation all over the region, and especially in the areas covered by the formations above the Homewood. Furthermore the elevations were obtained by means of aneroid barometers, which are liable to sudden variations and have to be constantly checked against spirit-level elevations. In spite of these sources of error, it has been thought advisable to draw structure contour lines. These show the generalized surface formed by the top of the Homewood sandstone, and, less precisely, the lay of the overlying and underlying beds. The limit of error may generally be considered a contour interval, but where the beds vary in thickness as they do in this area it may be more. This mode of presentation, in addition to showing the structure of the beds, enables us to estimate the elevation of the top of the Homewood sandstone when it is below drainage. For instance, near Zelda the 400-foot contour line was drawn. The elevation of Zelda is 580 feet above mean sea level; therefore, the top of the Homewood sandstone should be at a depth of 180 feet. The distances of the various coal beds above or below the top of this sandstone being known, their depth below the surface may in turn be estimated at this point.

DETAILED DESCRIPTION OF STRUCTURE.

This quadrangle lies at the southwest end of the great trough formed by the coal-bearing rocks of the Appalachian field. The axis of the trough extends southwest from near Pittsburg, Pa., and the trough reaches its maximum development near central West Virginia. From this point southwestward the axis slowly rises, crossing Ohio River a little east of the quadrangle and reaching Big Sandy River from 8 to 10 miles above its confluence with the Ohio. The axial line follows Big Sandy River southward for 2 miles and gradually curves to the west, pitching upward along a line practically coincident with the boundary between Carter County and Elliott

and Lawrence counties. The beds south of the axial line dip north and northwest, and those on the northern side dip southeast. The dips over most of the area are not very steep. In the northern two-thirds of the quadrangle the dips, with a few exceptions, do not average as high as 50 feet per mile. Near Catlettsburg the upper part of the Pottsville formation is exposed at railroad level, but across Big Sandy River the lowest rocks exposed in the cliffs along the Norfolk and Western Railway are the lower sandstone members of the Conemaugh formation; thus a dip of more than 50 feet per mile is involved between these points. Near Willard and southwest of this town in Carter County the dips are above the average, being close to 100 feet per mile. The steepest dips are confined to the southern third of the area. This belt of sharp dips is about 6 miles broad south of Louisa, but it narrows westward until at Blaine it is not more than a mile in width. West of this town the beds curve gently northwestward around the head of the basin. The dips in the ridge south of Louisa are fully 100 feet per mile. Near Adams and on Right Fork of Blaine Creek the rocks in places dip 300 feet per mile. The steepest dips in the area are near the mouth of Hood Creek in the eastern part of the town of Blaine. At the bridge over Hood creek the beds are inclined 11 degrees, and near this point two small faults were discovered by Mr. Ashley, but their throws are probably not great enough to materially affect the structure contours.

A few minor flexures are involved in the main syncline. In the region near Irad and Osie, Lawrence County, the Homewood sandstone thickens toward the west very rapidly, causing a slight arch in the overlying beds, but west of this district the sandstone is somewhat thinner and causes a slight depression. West of Cherokee Creek, approaching Elliott County, the structure seems to be rather irregular. This may be more apparent than real, and the irregularity in the contours may be due to the fact that they are based on but few outcrops and that the underlying sandstones, which might serve as a guide, thicken and cut out the coal beds. The flattening of the beds to the west is due to the dying out of the Appalachian folds as the Cincinnati arch is approached. West of this quadrangle the beds gradually rise to the apex of this arch, and this gradual rise is indicated in the contours west of Little Sandy River.

MINERAL RESOURCES.

GENERAL STATEMENT.

In an area of sedimentary rocks, like the Kenova quadrangle, in which the chief deposits are sandy or clayey, it is useless to attempt to find such metals as gold, silver, and lead in paying quantities.

ıall amounts of lead, zinc, and iron sulphides do occur in the clay-ıestone concretions in the shales of the Carboniferous system, but amount of such material is so small as to be entirely negligible, l time devoted to the search for the precious and base metals will fruitlessly spent. On the other hand, the coal and fire-clay beds y repay more careful prospecting than has heretofore been given ;m, and perhaps to a less extent this is also true of the alluvium the stream beds, the shale, the limestone, and the sandstone beds.

COAL.

Workable beds of coal are scattered through nearly the entire geo-;ic column, as developed in this area, up to and including the cele-ıted Pittsburg coal at the base of the Monongahela formation. e names, positions, and relationships of these coals are given in general columnar sections (Pl. IV) and also in the local sections. These coal beds vary somewhat in character but include most varie-s of the bituminous class. The bulk belong to the harder, bitumi-us variety, and in many places have a splinty aspect. The coals, as ule, break into rather thin slabs along charcoal layers, and hence y be classed as semiblock coals. As a rule they are unsuitable for ing, but after washing some of them give fair satisfaction. Coal . 6, or the Winslow coal, which has been mined for several years Winslow, has been washed and coked by the Ashland Iron and ning Company for use in the company's furnaces at Ashland, and always proved fairly satisfactory when mixed with a small ount of some standard coke or when coked with a small amount some standard coking coal. All the coals give excellent results en used for ordinary steam and domestic purposes. Nearly all ır well transportation and stocking. Coal No. 7, or the Coalton ıl, which ranks with and is stratigraphically equivalent to the nous Nelsonville coal of Ohio, has been and is still used by the hland Iron and Mining Company in its blast furnaces at Ashland. Ordinary bituminous coal is frequently associated with the splinty riety in most of the coal beds. It is finely interlaminated with a ll splint in many of the benches, and in other places it forms com-te benches by itself. This is sometimes the case with the Winslow ıl, the bottom bench of which is usually of the soft bituminous riety and contrasts with the harder splinty type of the two upper ıches. Certain beds in restricted areas contain benches of cannel ıl, for example, the coals now being worked by the Kentucky Cannel al Company at Boghead and Hunnewell. Sections obtained at ghead show the character of these two coals at this point.

Relations of coal and other important beds in the Kenova quad-

System.	Series.	Formation.	Names used in this report.
Carboniferous.	Pennsylvanian.	Monongahela.	Pittsburg sandstone
			Pittsburg coal
		Conemaugh.	Ames limestone
			Cambridge limestone
			Brush Creek coal
			Mahoning sandstone
		Allegheny.	Zelda coal
			Hatcher coal
			Red kidney ore
			Coalton coal
			Yellow kidney ore
			Winslow coal
			Iron ore
			Flint and plastic clay
			Vanport ("Ferriferous") limestone
			Flint and plastic clay
			Cat Creek coal
		Pottsville.	Homewood sandstone
			Lick Creek, Catletts Creek, or Upper Stinson coal
			Iron ore
			Torchlight or Lower Stinson coal
			Danleyton coal
			"Little Cannel" or Barrett Creek coal
			Massive sandstone
			Sharon coal
			Sharon conglomerate
			Salt sand
			Sciotoville fire clay
	Mississippian.	....	Iron ore
			Maxville limestone
			Waverly group
			Big Injun sand
			Sunbury shale
			Berea sandstone
			Bedford shale
Devonian.	....	....	Ragland sand
			Ohio shale

rangle, with names used in Pennsylvania, Ohio, and Kentucky.

Pennsylvania names.	Ohio names.	Kentucky names.
Pittsburg sandstone	...	
Pittsburg coal	Pittsburg coal	
Ames limestone	Ames limestone	
Pine Creek or Coleman limestone.	Upper Cambridge limestone	Upper Cambridge limestone.
Brush Creek limestone	Lower Cambridge limestone	Lower Cambridge limestone.
Brush Creek coal	...	
Mahoning sandstone	Mahoning sandstone	Mahoning sandstone.
Upper Freeport coal	Bayleys Run, Waterloo, or No. 7 coal.	No. 9 coal.
Lower Freeport coal	Hatcher or No. 6 A coal	No. 8 coal.
Middle Kittanning coal	Sheridan, Nelsonville, Straitsville, Lower Waterloo, Ashland, Mineral City, or No. 6 coal.	No. 7 coal.
Lower Kittanning coal	Newcastle or No. 5 coal	No. 6, Keyes Creek, River Hill, or Limestone coal.
...	...	
Vanport or Ferriferous limestone.	Hanging Rock or Ferriferous limestone.	
Brookville coal	No. 4 coal	No. 5 coal.
Homewood sandstone	...	
Upper Mercer coal	No. 3 A coal	No. 4 coal.
Lower Mercer coal	Lower Mercer coal	No. 3, McHenry's, or Torchlight coal.
Quakertown coal	Quakertown coal	No. 2 coal.
...	...	No. 1 or Barrett Creek coal.[a]
Sharon coal	Jackson Shaft coal	
Sharon conglomerate	Sharon conglomerate	
...	...	Maxton sand.
...	Sciotoville or Logan fire clay	
Greenbrier limestone or Big lime.	Maxville limestone	Subcarboniferous limestone.
	Waverly group	Waverly series.
Burgoon sandstone or Big Injun sand.	Logan formation (?), Black-hand formation, or Cuyahoga formation.	Big Injun sand.
...	Sunbury shale	
...	Berea sandstone	
...	Bedford shale	
...	...	Ragland sand.
...	Ohio shale	Ohio or Chattanooga shale.

[a] See p. 93.

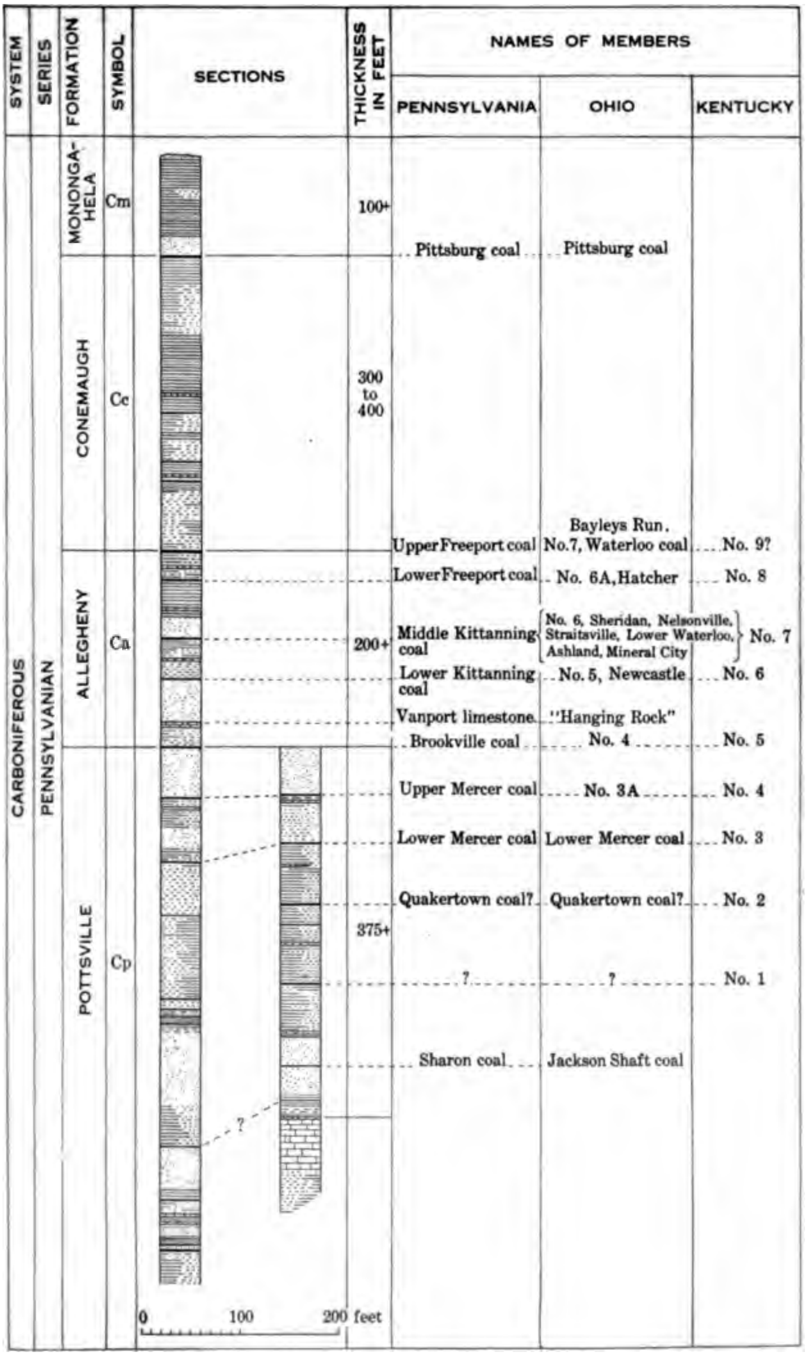
Section of No. 4 coal bed at Boghead.

Shale roof.	Inches.
Coal, bituminous	7½
Bone	½
Coal, bituminous	11
Fire clay	7¾
Bone	6½
Coal, cannel	9
	42¼

Section of No. 3 coal bed at Boghead.

Shale roof.	Inches.
Coal, bituminous	5
Bone	2
Coal, cannel	15
Fire clay	15
Coal, bituminous	14½
	51½

It is reported that the cannel layers are erratic in their occurrence, being as liable in No. 3 bed to occur in the top as in the middle bench. In the hill southeast of Hunnewell the middle bench is cannel coal. In Elliott County, near the western edge of the quadrangle, in the hills west of Stephens and north of Fielden, there is an important cannel bed well up in the top of the hill. Old openings were observed by the writer, but there was no opportunity to measure the coal. G. H. Ashley found the cannel layer 4 feet thick in places in the hills south of Critches Creek. This coal bed lies about 50 to 60 feet above the top of the Homewood sandstone and is tentatively correlated with the Winslow or No. 6 coal of the country to the east. On Hilton Branch, southwest of Willard, a rather thick bed of cannel has been worked in a small way. The seam was opened on the land of William Corey and Elijah Sturgill. At the opening on Mr. Corey's property the coal measured 29 inches of cannel with more lying below unseen on account of the water which nearly filled the opening. Mr. Sturgill, jr., reports 36 inches of cannel overlain by 8 inches of bituminous coal, capped by a sandstone roof. The Brush Creek coal of Lawrence County also contains a cannel layer. Besides these beds of cannel coal there are others containing sufficient volatile hydrocarbons to class them with the cannel coals. This is the case with certain layers in the Torchlight or No. 3 coal of Levisa Fork, Lawrence County, while the "Little Cannel" bed lying 140 feet below No. 3 at Torchlight contains a band whose analysis shows 55 per cent of volatile matter. Pl. IV and the table on pages 26–27 show the relations of the various coals and their equivalents in Pennsylvania, Ohio, and Kentucky.



GENERAL SECTIONS SHOWING RELATION BETWEEN THE COALS IN THE KENOVA QUADRANGLE AND THEIR EQUIVALENTS IN PENNSYLVANIA, OHIO, AND KENTUCKY.

CLAY.

The clays of the Kenova quadrangle are all sedimentary in origin and have reached their present position through the agency of water. They may be divided as regards both age and adaptability into two classes. First, the bedded clays, and, second, the recent unconsolidated silts or clays of the stream valleys. Of the former class two beds are prominent.

The higher of the bedded clays is that occurring near the horizon of the Vanport ("Hanging Rock") limestone, about 10 to 40 feet above the top of the Homewood sandstone. Though not so important as the lower fire clay at Olive Hill (the Sciotoville clay of Ohio) in the northeastern part of Kentucky, yet, when taken as a whole, it is of far greater importance in the Kenova quadrangle. On the economic map the red line, except along Tygarts and Everman creeks, Carter County, may be taken as the outcrop of the Vanport ("Hanging Rock") limestone with its associated clay. Detailed descriptions of the characteristics of this clay, as noted at different localities, are given on pages 113–117.

The lower of the two important clays occurs a few feet above the Maxville limestone and is one of the most important fire clays of northeastern Kentucky and southern Ohio. This is the celebrated Sciotoville clay of the Ohio Geological Survey reports, less widely known as the Logan clay. It has been extensively mined at Sciotoville and in the region around Portsmouth, Ohio, and is also mined on a large scale at Olive Hill, Ky., and in the valley of Tygarts Creek, which cuts across the northwestern corner of this quadrangle. In this area the fire clay appears at a few points near the western boundary and these occurrences are described in detail on page 118.

The recent clays of the flood plains of the rivers and small streams are widespread, even the smallest streams having in places extensive deposits. Those which are worked at present are confined to the Ohio Valley, where there is a local market, cheap coal, and convenient transportation facilities. This flood-plain clay is suitable chiefly for ordinary building brick, tile, shingles, etc.

Other important clays are found, but they are not so persistent as those noted above. Among those of less importance is the fire clay associated with coal No. 4 at Ashland and Catlettsburg and in the hills northwest of Willard, near the headwaters of Johns Creek.

Besides clays proper there is in the Carboniferous rocks over the entire quadrangle an abundance of raw material, such as ganister (siliceous clay) and numerous shale beds, which thus far has not even been prospected. This no doubt would make brick of fair grade,

MISCELLANEOUS ECONOMIC PRODUCTS.

The less important resources of this area are limestone and iron ore, sandstone, oil, gas, glass sand, and salt. These commodities will be considered in detail in a subsequent part of this bulletin.

DESCRIPTION OF COAL RESOURCES BY DISTRICTS.

For convenience in reference and from a commercial rather than a scientific point of view the coal resources of this area are described by districts whose boundaries have been chosen so that each district may coincide as closely as possible with the country naturally tributary to a certain railway line or other highway of communication. These districts are as follows:

1. Ohio district.
2. Big Sandy Valley.
3. District tributary to the Louisville and Lexington Railroad, or Chesapeake and Ohio Railway district.
4. Little Sandy Valley, or main Eastern Kentucky Railway district.
5. District tributary to the southern terminus of the Eastern Kentucky Railway.

OHIO DISTRICT.

EXTENT.

Only the southern part of Lawrence County, Ohio, including parts of Fayette, Perry, and Upper townships, is included in the Kenova quadrangle.

STRATIGRAPHY.

The rocks exposed in Ohio comprise the whole of the Allegheny and parts of the Conemaugh and Pottsville formations. The total thickness represented is in round numbers about 600 or 700 feet. The following section, obtained near Coalgrove depot, gives an excellent idea of the Allegheny formation and the lower part of the Conemaugh as developed at this point. The numbers of the coals are those of the Kentucky series.

Section near Coalgrove depot.

	Feet.
Conemaugh formation:	
Sandstone, laminated	25
Shale, red and green	25
Limestone, fossiliferous (Cambridge)	1
Sandstone, laminated	20
Shale	10±
Sandstone, laminated	36
Allegheny formation:	
Coal bloom (*position of coal No. 9*).	
Concealed	50
Position of coal No. 8.	

Allegheny formation—Continued.	Feet.
Concealed and shaly sandstone	44
Coal No. 7.	
Sandstone, massive	33
Coal No. 6.	
Sandstone, massive	40
Clay, massive flint	$1\frac{1}{2}$–$1\frac{2}{3}$
Clay, plastic	5
Limestone ("Hanging Rock")	4
Fire clay	$1\frac{2}{3}$
Concealed	5
Probable position of coal No. 4.[a]	

e Conemaugh formation in the Coalgrove section is typical so s it goes, with the exception of the basal sandstone. This is not lly laminated, but is very massive near the eastern edge of the rangle (Pl. III, *B*, p. 14). The massive character of this basal ber is well shown near the Norfolk and Western Railway bridge North Kenova and on the county road joining the river pike of Burlington. This sandstone forms prominent cliffs nearly long Ohio River in this area and in West Virginia as well. The er beds of the Conemaugh, not shown in the section at Coal-e, are well exposed in the hills back of Burlington and Sybene n general away from Ohio River, and consist chiefly of red shale sandstone, occasional limestones, which are more or less per-it, and small coal beds, rarely of workable thickness. In the rn part of the Ohio district, in Fayette Township, the surface e country is made up chiefly of shales of the Conemaugh, with sandstones and small and unimportant coal beds. This region, gh very hilly, is fertile and well adapted to the growing of fruits farm products, and is under general cultivation (Pl. III, *A*,). Since this formation is of little economic interest, it will not onsidered further.

e Allegheny is fairly developed, with the exception of coal No. Ohio nomenclature, Pl. IV). This coal was not seen in the sec-at Coalgrove, but the higher coals were all seen at one point or ner in this State. The Allegheny formation is present in all the in Upper and Perry townships, but the eastern dips cause it to ppear near North Kenova, just east of the Norfolk and Western way bridge. The thickness of the Allegheny is about 180 feet. highest coal bed present in this formation is the Upper Freeport, h lies either immediately or at a small distance below the Mahon-sandstone. Its bloom is fairly widespread, though it does not to have been worked to any extent. This coal is the Waterloo o. 7 of the Ohio Geological Survey. Thirty to fifty feet below curs the Hatcher of the Ohio and Kentucky geological surveys.

[a] No. 5 in the Kentucky series.

In Ohio it is No. 6A and in Kentucky No. 8. E. McMillan[a] has correlated it with the Lower Freeport of Pennsylvania. The most important coal in this part of Ohio is found 100 feet below the base of the Mahoning sandstone. It is known as the Sheridan or No. 6 coal in Ohio. In Kentucky it is also important and is known as the No. 7 or Coalton coal. The Ohio geologists[a] have correlated it with the Middle Kittanning coal. Between these three coals are two beds of limestone, in many places associated with iron ore. The massive sandstone overlying the Coalton coal serves as a means for locating and following it. About 30 to 40 feet below the Coalton coal another persistent bed is found, known as the Newcastle coal, or No. 5 bed (No. 6 of Kentucky). It is best seen at Coalgrove, where it lies 33 feet below the Coalton coal, the interval being occupied by a very massive sandstone.

The lowest stratum of economic importance in the Allegheny is the clay associated with the Vanport ("Hanging Rock") limestone. The bed is about 75 feet below the Coalton coal and is capped by a very massive sandstone. No other beds of economic value were seen above drainage level in this area.

Only a very small part of the Pottsville formation is shown, probably not more than 20 to 25 feet, and this is in the vicinity of the Coalgrove section. The Homewood sandstone outcrops near Coalgrove depot, and although No. 4 coal of the Ohio Survey, or that resting directly on the Homewood sandstone, is not known in this immediate neighborhood, it has been recognized in the vicinity of Ironton, not more than a mile to the west, by the Ohio geologists.[b]

THE COALS.

UPPER COALS.

The upper coals in the Allegheny formation and the coals in the Conemaugh have little or no importance in this part of Ohio. The Hatcher coal, No. 8 of the Kentucky Survey, and the Upper Freeport have been opened in a few places on Lick Creek, about 1½ miles east of Sheridan, and near the residence of R. H. Henshaw on Little Ice Creek. In the summer of 1905 openings on these upper coals were fallen shut and no measurements could be obtained. According to the Ohio State reports the Upper Freeport coal, which is known as the Bayleys Run or Waterloo coal, is 4 feet thick near Ironton,[b] and in the general section given by McMillan[a] it is represented as averaging 6 feet. In quality these coals are inferior to the

[a] Ohio Geol. Survey, vol. 5, 1884, p. 122.
[b] Ohio Geol. Survey, vol. 3, pt. 1, 1878, section opposite p. 928.

Coalton coal, and under present conditions probably could not be marketed. They have furnished up to the present time a small amount of fuel for local consumption and will probably continue to do so for a number of years.

SHERIDAN COAL OF OHIO (COALTON COAL OF KENTUCKY).

Position.—The Coalton coal is 100 feet below the Upper Freeport coal and about 50 feet below the Hatcher or Lower Freeport bed. It has been correlated with the Middle Kittanning coal of Pennsylvania. In this report the name Coalton coal will be applied to this bed, since in Kentucky it was originally worked at Coalton, and was widely known under this name.[a] It is the second bed above the Vanport ("Hanging Rock") limestone and ore.

Extent.—This coal has been known and worked for many years in the Hanging Rock region. According to the Ohio Geological Survey reports,[b] it is identical with the celebrated Nelsonville or Straitsville coal of the Hocking Valley. Up to the present time it has proved to be by far the most important commercial coal in this quadrangle, and in Kentucky much of it lying above drainage level has been removed. In Ohio, however, little has been removed above drainage level and none below.

As it occurs 30 to 40 feet above the next lower coal its outcrop will be found above drainage level farther to the east than the outcrop of the lower bed, but the area above drainage level underlain by it is comparatively small, being not more than one-tenth of that part of Ohio included within this quadrangle. It is present in all the hills near Coalgrove, Forestdale, and Sheridan; in the hills well up on Little Ice Creek, and also along Ohio River to a point about 2 miles above Sheridan. (See Pl. I.) Beyond this point it is hidden by the flood-plain deposits. Near North Kenova, just east of the bridge, no flood plain is present, and a coal which may possibly be referred to the Coalton bed lies nearly at the river's edge. It is about 55 feet below road level and is now worked in a small way by B. J. Davidson and Will Dillon. West of the bridge a few old openings on this bed were observed, but they are fallen shut and the thickness of the bed could not be determined. Just east of the Davidson and Dillon openings the coal disappears below Ohio River.

Development.—This coal is not now worked on a commercial scale, but the reason is evidently not the scarcity of material, as there is an ample supply of good coal still above drainage level. The old Sheridan Company ceased operations more than twenty years ago.

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[a] Kentucky Geol. Survey, vol. C, 1884, p. 122.
[b] Ohio Geol. Survey, vol. 3, pt. 1, 1878, pp. 917–918.

At present the coal is of importance simply as a source of local supply and has been opened at many points where its outcrop approaches drainage level, notably on Little Ice Creek and its branches east of Forestdale, and in the hills along Ohio River near Sheridan.

Character.—The Sheridan coal in general ranges in thickness from about 3 to 4 feet, but in places exceeds the latter figure. As a rule it has a small bony parting, an inch or less thick, lying from 2 to 14 inches from the roof. The upper of its two benches is usually about a foot thick; the lower or main bench varies from 2 to 3 feet. Southeast of Lick Creek the two benches are represented by a single bench of 25 to 27 inches (section 3, fig. 1). The different measurements of this bed obtained in this field are given in fig. 1. It is possible that a third bench exists in places, for in Kentucky this very commonly appears.

The Coalton coal is a hard, splinty coal, breaking along charcoal layers into slabs, which range from 6 to 8 inches in thickness. It is

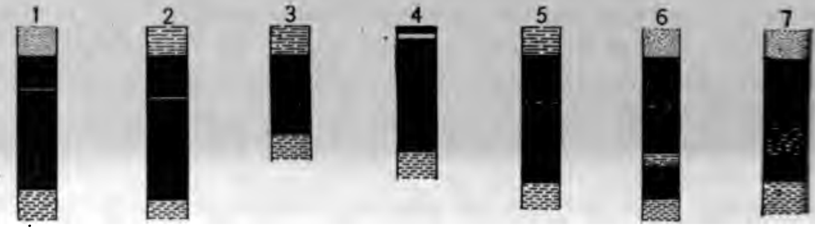


FIG. 1.—Sections of Allegheny coals in Ohio. Coal No. 7: 1, Elizabeth Wise, Little Ice Creek; 2, John Ide, Sheridan; 3, William Talbot, 1 mile southeast of Sheridan; 4, Henry Wineka, Lick Creek; 5, east of Forestdale. Coal No. 6: 6, country bank north of Coalgrove; 7, Harry Smith, north of Coalgrove. Scale, 1 inch = 5 feet.

too high in sulphur to make a first-class coke, therefore it will be used chiefly as a steam and domestic coal, being well adapted for stove and grate use. The analyses of this coal, given on page 71, are discussed on pages 71–72.

The roof of the coal is in some places massive sandstone and in others shale. The sandstone which overlies or underlies the coal becomes abnormally thick in places and cuts it out almost completely, leaving but a few stringers of coal to represent the bed. Such is its condition along the Ohio River, opposite the eastern suburbs of Ashland, where the sandstone of the lower part of the Allegheny formation is abnormally thick. For this reason the coal is not visible in many places where its horizon is exposed. It is reported also to be absent just west of Forestdale.

Economic features.—Owing to the southeast dips which prevail in this district the proper points for opening mines on this coal bed are on the southeast flanks of the hills. In sinking shafts care should

: exercised to place them with a view to working up the dip or in a ›rthwest direction. The situation of the district with respect to arket and transportation could hardly be improved. Many of the rge cities of Ohio and Kentucky lie within a radius of 100 miles, ıd either railway or the very much cheaper river transportation convenient, the Ohio being navigable the year around well above is point.

No estimate is attempted of the amount of coal of workable quality. may be sufficient to state here that the Coalton bed underlies about ne-tenths of that portion of Ohio included in this quadrangle, and ere is no apparent reason for supposing that it will not prove work- le in almost its entire area.

NEWCASTLE COAL OF OHIO (WINSLOW COAL, OR NO. 6, OF KENTUCKY).

Extent and development.—The lower of the workable coals in Ohio s been called in the State reports the Newcastle or No. 5 coal, and considered by Orton and the Ohio geologists as the equivalent of e Lower Kittanning coal of Pennsylvania. (See Pl. IV, p. 28.) s it is the first coal bed of importance above the Vanport ("Hang- g Rock") limestone, it is locally called in Kentucky the "Limestone al," a name which is also applied to it about Coalgrove, Ohio. It worked on a commercial scale at Winslow, Boyd County, Ky., and erefore will be called in this report the Winslow coal. It is found varying distances above the Vanport limestone, but it will average feet above this bed and 30 feet below the Coalton coal. From the ctions given on page 36 and in fig. 1 it will be seen that this al lies below heavy sandstones at Coalgrove. Its outcrop is not dicated on the economic map, but, if drawn, would appear be- veen that of the Vanport limestone, represented in red, and that of ıe Coalton coal, represented in blue. It will be seen that its outcrop not of great extent, because the eastern dips carry it below drainage vel. Where exposed it has been opened in many places, and it is ow mined on a commercial scale near the base of the hill northwest f Coalgrove depot. Several country banks are working this coal ear Forestdale, east of which the coal is below drainage level. long the river pike this coal has been worked in a very small way at ne or two points, but the linear extent of its outcrop here does not xceed a mile.

Character.—The two sections given in fig. 1 (p. 34) illustrate well ıe character of this coal. The first section, obtained just north of 'oalgrove depot, is more typical than that measured at the country

bank of Harry Smith, as the bed usually occurs in three benches, which may vary as shown in the following section:

General section of Winslow coal, near Coalgrove.

	Inches.
Sandstone.	
Coal	8–16
Bone	1– 3
Coal	15–16
Shale	4
Coal	8–16

The bed is apt to be irregular in thickness, and the maximum figures given above were obtained at only one point. A fair average thickness is 3 or 3½ feet. The massive sandstone which overlies the bed furnishes an admirable roof, and little timbering is necessary. On the other hand, this sandstone is liable to roll and it may replace the coal completely. The coal is dry, of good quality, and well adapted for heating purposes. It does not furnish a good grade of coke, owing to the presence of a large amount of sulphur, but after washing it is suitable for coking. The coal mined at Coalgrove is shipped over the Norfolk and Western Railway to Portsmouth, Ohio.

BIG SANDY VALLEY DISTRICT.

EXTENT.

The Big Sandy Valley district includes that portion of this quadrangle whose natural outlet is along Big Sandy River. It includes all of Wayne County, W. Va., within the limits of this quadrangle, except that part whose outlet is along Twelvepole Creek; but as this small area is of little importance from an economic standpoint, it may be said that all of West Virginia included in this quadrangle has its natural commercial outlet along Big Sandy River. This district extends as far west as the ridge dividing the waters of Big Sandy from those of East Fork of Little Sandy River. The northwestern corner of this division is the summit of the ridge between Shope and Chadwick creeks, Boyd County. Southwest of this point the boundary is a sinuous line along the ridge mentioned, which lies east of Alley, Bolts Fork, and Estep. In this district is included Cooksey Fork and Cat Creek. From the head of Cooksey Fork the line marking the western boundary of the district passes to the confluence of Daniels Creek and Blaine Creek, thence along the latter creek to the south. It passes out of the quadrangle along the ridge immediately west of Rich Creek. (See Pl. I.)

STRATIGRAPHY.

This district includes the widest range of coals in the entire quadrangle, comprising, indeed, all the coal horizons here represented. All the coals, however, are not developed in this district on a work-

ıble scale, and a few beds appear not to have been formed at all in ›laces. On account of the comprehensive character of the geologic :olumn the description of this district will serve as a natural introluction to those which follow.

All the geologic formations represented in the quadrangle, with he possible exception of those of the Mississippian series, are devel›ped in the Big Sandy Valley. The highest rocks represented belong o the Monongahela formation. This formation is only partly de'eloped and is of very small extent, occurring in the hills which carry he Pittsburg coal near the mouth of Gragston Creek, Wayne County, V. Va. This is the only locality in this quadrangle where rocks of his formation are present. Its most important member is the Pitts›urg coal lying at its base. This is capped by the Pittsburg sandtone, which is about 30 feet thick and is very massive. The remain.er of this formation is composed of reddish shales and sandy ediments. About 100 feet of the formation are still left in the hills. See Pl. IV, p. 28.)

The Conemaugh formation is completely developed in a small area n this quadrangle near the mouth of Gragston Creek, Wayne County, V. Va., in the deepest part of the basin. In the tops of the highest .ills near the mouth of this creek is the Pittsburg coal mentioned in he last paragraph, the floor of which marks the top of the Coneıaugh formation. The thickness of the Conemaugh is more than 300 eet. It is composed chiefly of shales, together with limestone and few thin coal beds. It also contains sandstones which, with certain xceptions, are liable to be lenticular, and on this account are poor tratigraphic guides. The rocks of this and the overlying Mononahela formation are the poorest in the area with reference to coal esources, the only really valuable coal associated with them being the 'ittsburg bed, which occurs in too small an area to be of great ecoomic importance. The rocks of this formation, although a complete ection is shown only over a very small area, are yet widespread over he surface of this district, occupying possibly two-thirds of the ntire area.

The Allegheny, the next lower formation, is about 160 feet thick. . section of Allegheny rocks may be seen along the road northwest f Louisa from a point near the confluence of Canes Branch and Twoıile Creek. The massive sandstone at the top of the Pottsville is in he roadbed at drainage level, and not far away the Winslow, or No. , coal bed has been opened 30 feet above it. At the forks of the road ıear the head of Canes Branch one of the lower limestones of the 'onemaugh formation is present, with another limestone 40 or 50 eet below it on the west side of the ridge. The Mahoning sandstone, ying 50 feet under this lower limestone, is rather massive. West of his ridge, as Blaine Creek is approached, the sandstone at the top of

the Pottsville becomes abnormally massive and thick. The Allegheny here loses some of the distinctiveness which characterizes it in the northern part of the quadrangle, and its upper boundary is somewhat doubtful. Southward from the region around Louisa the rise in the beds causes the gradual disappearance of the Allegheny from the hills. North of this point the formation gradually descends to the center of the basin, until at Zelda the highest coal in the formation disappears below the flood-plain deposits. A rise in the beds brings the Allegheny above drainage level again north of Savage. The formation is present in whole or in part in nearly all the hills in the southern third of the Big Sandy Valley district and also at the north end of the district near the mouth of Big Sandy River. The coals of the Allegheny are not so well developed in this district as to the north and west. The thickness of the formation along Big Sandy River, north of Louisa, seems to be about the same as near Ashland and Coalgrove, 160 to 180 feet.

The Pottsville formation is well developed in the southern part of the district, and a fairly good section was compiled on the Chesapeake and Ohio Railway, along Levisa Fork and in the surrounding hills. This section was measured south of Louisa and is as follows:

Section of Pottsville on Levisa Fork south of Louisa, Lawrence County, Ky.

	Ft.	In.
Sandstone, massive, Homewood [a]	40–60	
Coal No. 4, Lick Creek coal (Upper Mercer).		
Ore, black band	8–12	
Concealed	20	
Sandstone, massive	20	
Shale or sandstone	15	
Coal No. 3, Torchlight (Lower Mercer).		
Probable shaly sandstone	50–60	
Coal		4–8
Probable sandstone	21	
Concealed, but probably shaly sandstone	19	
Concealed	17	
Sandstone, laminated	5	
Concealed	20	
Shale with five small coal beds, the topmost of which is the so-called "Little Cannel seam"	32	8
Sandstone, massive	40–100	
Interval	30±	
Shale, drab	5	
Shale, black	3	
Shale, dark	4	
Coal (*Sharon?*)	1	4

[a] It is probable that south of Louisa, where this sandstone is very massive and apparently homogeneous throughout, it is not wholly of true Homewood age. Its lower part probably belongs under coal No. 4, which was cut out in places by a thickening up of the lower sandstone member. In this case only the top should be regarded as true Homewood sandstone.

	Ft.	In.
Shale and sandstone	5	
Coal bloom		6
Sandstone, massive (Sharon)	40±	
Shale	10	
Coal bloom	1	
Shale and sandstone	10	
Shale	5	
Limestone, blue		8
Shale, gray	2-5	
Limestone, blue	1	
Shale, dark	5	
Sandstone	4	
Shale	3	
Coal bloom	1-2	
Shale	3	
Coal bloom.		
Sandstone, massive	4	
Coal bloom.		
Fireclay		8
Sandstone		1½
Concealed	20±	
Sandstone, shaly, micaceous	10	

[t will be seen that in general the section shows several massive ıdstone groups, between which are intervals containing coals, ıles, shaly sandstones, limestone, and iron ores, the total thickness which is approximately 600 feet. The general sandy character this formation is also noteworthy.

n the section certain Pennsylvanian equivalents have been inserted parentheses. These correlations have been based on studies made David White. The bed worked at Torchlight, known at the Torchıt coal in this report, is regarded by him as the equivalent of the er coal worked at Boghead, Carter County, and both the lower l the upper coals worked on Stinson Creek at Boghead fall within Mercer group of northwestern Pennsylvania. It would seem, refore, that the Torchlight (No. 3) and No. 4 probably correspond he lower and upper Mercer coals, respectively.

The reference of the group of thin coals, of which the "Little ınel" is one, to the Sharon or No. 1 horizon is furthermore not tained by the paleobotanic evidence, according to White. This ıup occurring in the interval of 32 feet 8 inches at railway level th of Torchlight represents a higher horizon than the Sharon. e coal underlying the massive sandstone, which begins to be promiıt in the hills back of Chapman, is probably the representative of Sharon in this section. At Gallup a lower sandstone is 50 to 60 t above railroad grade, and a short distance north of the store it 50 feet thick. This is probably the Sharon sandstone.

It will be observed that the portion of the Pottsville below the sandstone at Gallup (Sharon) is characterized, within the limits of the quadrangle, by the development of dark shales and gnarly cauda galli flags, including some limestones and coals of variable thickness.

THE COALS.

MONONGAHELA COAL (PITTSBURG BED).

In the tops of the hills near the center of the basin there is about 100 feet of the Monongahela formation. At its base is a coal which is referred to the horizon of the Pittsburg bed, though it is hardly comparable in thickness with this famous bed in West Virginia and Pennsylvania. It is nevertheless a coal of excellent quality, and only its very moderate area of not more than a few acres prevents its commercial exploitation. In the hills east of Lett, at the mouth of Gragston Creek, it has been opened on the land of Abraham Thacker and James Adkins, and is found to range in thickness from $2\frac{1}{2}$ to $4\frac{1}{2}$ feet. It averages about 3 feet and usually has a thin but strong shale roof overlain by massive sandstone 20 to 30 feet thick. The section obtained at one of the openings on the land of James Adkins illustrates the character of this bed (see fig. 2).

FIG. 2.—Section of Pittsburg coal at bank of James Adkins in hill west of Centerville, W. Va. Scale, 1 inch = 5 feet.

CONEMAUGH COALS.

It has been stated that the Conemaugh formation is in marked contrast with that lying below, both in the character of its rocks and in the fact that it contains no workable coals and only here and there a bed of iron ore. In the Big Sandy River Region this description holds fairly good with one exception. In the hills back of Cassville a small coal, called by I. C. White[a] the Mason coal, is found in the group of sandstones at the base of the Conemaugh. It is 2 feet thick. The same coal bed has been opened at a few points along Twelvepole Creek a few miles above Ceredo. It is as a rule so thin and so variable in its distribution that it can hardly be classed among the important coals of the future. It has now and may continue to have some local importance. With the exception of this bed the Conemaugh formation is probably devoid of workable coals.

[a] West Virginia Geol. Survey, vol. 2, 1903, p. 280.

ALLEGHENY COALS.

SECTIONS OF THE FORMATION.

he base of the Allegheny formation appears in the hilltops about r 8 miles south of Louisa and dips rather steeply to the north, ıg very nearly at railroad grade at Eloise and a few feet below road level at Louisa. There are at least five workable coals in Allegheny in different parts of this quadrangle, but in no single rict are all these of workable thickness. Usually not more than or three are workable in any particular locality. This is true the region about Louisa and for the valley of Big Sandy River a whole. A section obtained near Cassville will illustrate the racter of the beds in the Allegheny formation.

Section at Cassville.

	Ft.	in.
Top of hill.		
Concealed and sandy débris	15	
Sandstone, massive	28	
Shale	3	
Shale, fossiliferous [a]	4	
Coal	2	
Sandstone, conglomeratic in places, with calcareous nodules about 15 feet from its top	53	
Probable top of Allegheny.		
Concealed	22	
Sandstone, massive	20	
Clay, flint.		
Shale, green	1	6
Shale, red	1	
Shale	12	6
Concealed, but containing a coal near the top	20	
Sandstone, laminated or shaly	1	
Shale, sandy	9	
Shale, greenish, and sandy shale	25	
Coal smut		2
Fire clay, green	3	
Sandstone	2	
Fire clay, drab	1	6
Shale, sandy	12	
Sandstone, massive	4	
Fire clay		3–4
Sandstone, laminated	19	
Limestone ore, nodular	1	
Shale	3	6
Coal No. 6	1	9
Fire clay, upper part fossiliferous	2	
Shale, sandy	6	
Coal		1½

[a] This shale is regarded by I. C. White as the representative of the lower Cambridge estone and the coal underlying it as the Mason: West Virginia Geol. Survey, vol. 2, 3, p. 280.

	Ft.	In.
Shale, green, fossiliferous	1	
Coal		5
Fire clay		6
Fire clay, siliceous	6+	
Concealed	7	6
Railroad grade.		

The lower part of this section was measured also in the first main cut on the Chesapeake and Ohio Railway, about a mile north of Louisa.

This section, which shows the variations that may take place within a short distance, is as follows:

Section north of Louisa.

	Ft.	In.
Coal	1	
Sandstone, laminated	2	
Coal		6
Shale	3-5	
Sandstone, laminated	4	
Fire clay		6
Sandstone, laminated	2	
Limestone, ferruginous		4-5
Fire clay	1	
Sandstone, laminated	2-3	
Fire clay, with nodular limestone	1	
Sandstone, laminated	3	
Limestone nodules, intermittent layer		6
Shales, drab, or fire clay	4	
Coal, changing to black flint		6
Fire clay	2	
Coal	1	6
Shale, dark fossiliferous	4	
Bone		6
Shale, drab fossiliferous	1	6
Coal		6
Fire clay, siliceous	5	
Railroad level.		
Fire clay, siliceous	3	
Concealed	3	
Shale, drab	5	

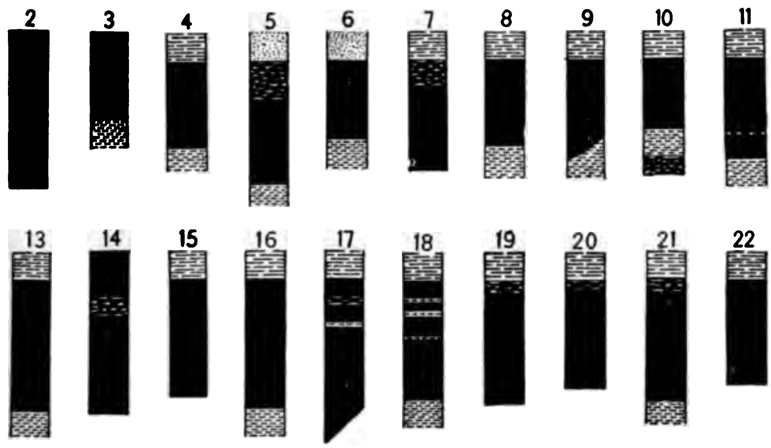
These two sections, obtained on opposite sides of the confluence of Tug and Levisa forks, illustrate well the character of the coal-bearing rocks in this vicinity. The sandstone member forming the top of the Pottsville is exposed at the mouth of Lick and Mill creeks, south of Louisa and Cassville; also at the lock just a short distance down Big Sandy River from Louisa, and at the mouth of Canes Branch. Its top, therefore, must be only a few feet below the flood plain on which the towns are built. This statement is corroborated by the evidence of the fossil plants, examined by David White, from the fossiliferous beds indicated in the lower parts of the above sections.

ZELDA COAL (NO. 9).

ame and position.—The Zelda coal is the No. 9 of Kentucky and No. 7, Bayleys Run, or Waterloo coal of Ohio.

ıe highest coal of importance in the Allegheny formation in Big ly Valley usually occurs below a rather massive sandstone which, reasons already stated, is regarded as the Mahoning sandstone. coal below this sandstone, the Zelda coal, is thought to occur at ıorizon of the Upper Freeport coal.

xtent and development.—In the valley of Big Sandy River the a coal has been prospected at a number of points. The rise of beds up Big Sandy River brings this coal above drainage at



}.—Sections of Zelda coal (Upper Freeport, Kentucky No. 9). Kentucky: 1, Clifton ın, near Zelda; 2, Frank Yates, near Catalpa; 3, 1 mile north of Fallsburg; 4, tthew Holley, mouth of Cat Creek; 5, 1 mile above No. 4; 6, C. C. Crank, Fallsg; 7, west of Fallsburg; 8, John Bentley, Yatesville; 9, Wade Chapman, Yatesville. st Virginia: 10, on Norfolk and Western Railway, north of Miller Creek; 11, Alvin wart, opposite Zelda; 12, mouth of Little Hurricane Creek; 13, Christopher Bellamy, tle Hurricane Creek; 14, Elijah Thompson and William Wellman, Little Hurricane ek; 15, Isaac B. Fish, Tabor Creek; 16, John Thompson, Long Branch of Tabor ek (only main bench is shown); 17, Volney Artrip, head of Right Fork of Hurricane ek; 18, head of Trace Branch; 19, 20, 21, near Bellups Gap; 22, Tug Fork. Scale, nch = 5 feet.

a, where it has been opened on both the Kentucky and the West ginia side of the river. Just south of Zelda 26 inches of coal measured at the bank of Clifton Dean (fig. 3, section 1). A t distance north of Dean's bank E. D. Milan has opened the same . South of Zelda it has been opened and worked in at least half zen places near the mouth of Mill Branch and at Gurnetts, where ınges from 2 to 3 feet in thickness. Southwest of Catalpa it has ı opened by Frank Yates, of Louisa, 48 feet above the railroad k, where it measures a little over 4 feet thick (fig. 3, section 2). s coal has also been opened near the mouth of Horseford Creek, he property of Dr. John Berry, of Quincy, Ky. At this point

only 1 foot of coal is exposed, beneath a shale and sandstone roof, but the bed is reported to be 3 feet thick. South of Fuller, owing to the rise of the beds, the massive sandstone capping this coal may be seen from the railroad at a few points; but the coal underlying it has not been opened, except near the heads of some of the shorter streams which flow into Big Sandy from the west.

Fallsburg district.—The rise of the beds toward the south brings the coal bed above drainage level on Blaine Creek at the mouth of Long Branch, about 1 mile north of Fallsburg. Here it has the section indicated in fig. 3, section 3. A short distance to the south, near the mouth of Cat Creek, a section (4, fig. 3) almost identical with section 3 was seen at Matthew Holley's bank. The coal farther in the bank is reported 33 to 34 inches where thickest. About a mile farther up Cat Creek a section (5, fig. 3) showing about 25 inches of coal furnishes added evidence of the uniformity of the coal in this vicinity. The following section was measured east of Fallsburg:

Section east of Fallsburg.

	Feet.
Soil, sandy.	
Limestone débris.	
Soil, clayey.	
Shales, green	60
Sandstone	5
Limestone, crinoidal	2- 3
Fire clay	1
Shale, red and green	20-25
Shale	20
Clay	4
Sandstone	45
Sandstone, massive	20
Coal bloom, Zelda.	

This section shows well the character of the beds above the Zelda coal in this region. The coal at the base of the section has been opened at a number of country banks in and about Fallsburg, where it averages about 2 feet thick, as sections 6 and 7 (fig. 3) show. West of Yatesville, at the banks of John Bentley, Wade Chapman, and James Compton, the coal bed is reported as ranging from 2 to 3 feet, and these figures were verified in several places (sections 8 and 9, fig. 3).

West Virginia.—The sandstone overlying the Zelda coal disappears below drainage level a short distance north of Zelda and is not exposed again until it rises above drainage level on the north side of the basin near Savage, Ky. From this point to the mouth of Big Sandy River no coal was seen immediately below the sandstone, but in a bed of shale, 20 feet or so below, an occasional bloom was noticed which may correspond with Crandall's No. 8, or the Hatcher bed. In West Virginia, near the mouth of Big Sandy River, the basal

dstones of the Conemaugh are a very conspicuous feature in the dscape, and in recent cuts along the Norfolk and Western Railway ɔal bed occupying a position corresponding to that of the Zelda l was observed near the mouth of Miller Creek. This is the coal worked by Will Payne, a short distance above the mouth of the ɛk. It is reported to be 32 inches thick at Payne's bank, though, vill be seen from section 10 (fig. 3), it is very badly split by parts along the railroad. South of Neal it disappears below the flood in. Farther east, on Whites and Gragston creeks, the horizon of ; coal is above drainage, and in a few places the bed attains a ·kable thickness. Opposite Zelda, at Alvin Stewart's, the coal ws a thickness of very nearly 40 inches (section 11, fig. 3). About bbardstown and along Hurricane Creek both this coal and the next lerlying bed outcrop in several places. The lower of these two ls is rarely of workable thickness, but the higher coal has been ned in several places and shows a thickness of 2½ to 3 feet and re (sections 12, 13, and 14, fig. 3). About a mile east of Hubbardsʼn the bed does not appear to be of sufficient thickness to work, but .r the mouth and near the headwaters of Tabor Creek it has an ɪrage thickness of 3 feet (section 15, fig. 3), and in places, inɪd of a single bench, consists of two benches, as indicated in the lowing section, measured at the bank of John Thompson:

Section at John Thompson's bank, Tabor Creek.

	Inches.
Sandstone roof.	
Coal	6½
Shale and fire clay	37½
Coal	39½
Fire clay.	

Ƴortheast of Cassville, on the headwaters of Right Fork of Hurri.e Creek, and still farther northeast, on Trace Branch, sections (17 l 18, fig. 3) measured at the country banks working this coal give ood idea of its persistence and character. This coal has also been ɪned at one or two points on Mill Creek.

⁊he coal opened just north of Bellups Gap is tentatively referred :his bed, but it may be a lower coal. It has been opened by Poley ·guson and James Bellup. This is probably the same coal opened ; than a mile northeast of Louisa, which has a similar section (secɪs 19, 20, and 21, fig. 3). The coal opened near Copley on Tug ·k is also regarded as a lower bed than the Zelda coal and may sibly be as low in the formation as the Coalton coal (section 22, 3).

ʾharacter.—From sections of the Zelda coal given in fig. 3, it will seen that it consists in general of a single bench ranging in thicks from 2 to 3 feet. It usually has a thin black shale or bone roof,

but is in many places overlain by massive sandstone. It rarely exceeds 2½ feet in thickness, and the measurement of 4 feet obtained at Frank Yates's bank, southeast of Catalpa, is apparently local. The coal is a lustrous, bituminous, semiblock coal, with splinty partings, and is highly esteemed for smithing and domestic purposes. The chief objection is to its thin section. Its quality apparently bears a certain relation to the thickness of the bed, for the thicker coal is reported to be of poorer quality at the head of Little Hurricane and Tabor creeks. It is quite probable that it will prove commercially valuable at some future time in the area indicated by the solid outcrop line. (See economic map, Pl. I.)

COALTON COAL (NO. 7).

The Coalton is the next lower coal bed in the Allegheny formation. Taken as a whole, this coal is the most important in the entire quadrangle, but in the valley of Big Sandy it is of minor importance. About two-thirds of a mile south of Potters a coal referred to this

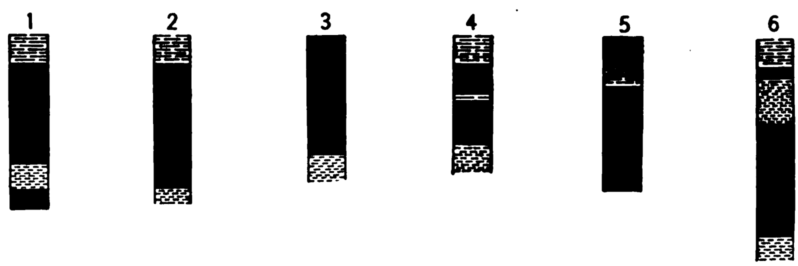


FIG. 4.— Sections of the Coalton and Winslow coals in Big Sandy River district. Coal No. 7 (?): 1. George Cooksey, Cat Creek; 2, Cat Creek; 3, Cat Creek. Coal No. 7: 4, two-thirds of a mile south of Potters. Coal No. 6: 5, T. J. Chapman, Lick Creek; 6, John Vaughn, Lick Creek. Scale, 1 inch = 5 feet.

horizon outcrops at railroad level, but is thin (fig. 4, section 4). This coal has been worked just north of the station.

On Cat Creek, below the mouth of Thompson Fork, a coal which is doubtfully referred to this horizon has been opened about 40 to 50 feet above the road. It is closely overlain by a rather massive sandstone, and in this respect resembles the Coalton coal, but the distance below the base of the massive sandstone forming the lowest member in the Conemaugh formation points to a higher bed. It may therefore be the next higher, or Hatcher, coal. Along Cat Creek it is not over 50 feet below the base of the Mahoning sandstone, whereas the ordinary distance below that sandstone of coal No. 7, or the Sheridan bed, around Ohio River is from 90 to 100 feet. It is certain that the usual number of coals is not developed in the Allegheny rocks along Cat Creek below the mouth of Thompson Fork, as the section in the hill between Cat Creek and Morgan Run indicates. The coal under

consideration has been opened on the property of W. A. Rice, John Cooksey, Willis Roberts, J. K. Chadwick, Mrs. Americus Wood, and Mrs. Nancy J. Carter, on Cat Creek, and also in the vicinity of Yatesville. Sections 1, 2, and 3 of fig. 4 illustrate the character of this bed in the valley of Blaine Creek.

WINSLOW COAL (NO. 6).

In the section given on page 42, above the railroad level a mile north of Louisa, there is a bed of coal $1\frac{1}{2}$ feet thick 11 feet above the railroad track. In places this coal measures from $27\frac{1}{2}$ to 29 inches, with a drab or black shale roof a foot or two thick and a clay floor. It is the same bed which has been opened in the hills west and northwest of Louisa and is probably the coal referred to as coal No. 6 in Crandall's report; also, it is probably the bed which is mined so extensively about Ashland and Winslow, in Boyd County, and at Coalgrove, Ohio. At these different places it is known as the limestone coal, from its position as the first coal above the Vanport ("Hanging Rock") limestone. Though it is worked extensively about Ashland, it has been thought best not to apply the name of that city to it, as the coal next above (the Coalton coal) is frequently referred to in the Ohio reports as the Ashland coal.[a] It is being mined and shipped from Winslow, south of Ashland, and hence may appropriately be known as the Winslow coal. In the Ohio reports it is usually termed the Newcastle coal. As the first coal above the Vanport limestone it corresponds, in position at least, with the Lower Kittanning or Miller bed of Pennsylvania.

Though this coal bed has been opened in many places near Louisa, only a few measurements could be obtained, as nearly all the banks in which the coal has been worked have fallen shut. Near the mouth of Twomile Creek and on Lick Creek it has been opened and worked on a small scale. This is probably the coal opened by John Vaughn and T. J. Chapman. (See fig. 4, sections 5 and 6.) It is reported of workable thickness in the hills north of Chapman's store on Threemile Run, and a few old openings on it were seen at this place. On Dry Ridge south of Irad it appears as a small coal not exceeding 2 feet in thickness.

In West Virginia, south of Cassville, it has been opened, and $32\frac{1}{2}$ inches of coal were seen at an opening south of the town. On Mill Creek the coal has been opened at a few points, and though the upper part of the bed is somewhat injured by the presence of bone and shale, it usually contains a lower bench of bright, lustrous bituminous coal of good quality, averaging from 2 to 3 feet in thickness.

[a] Ohio Geol. Survey, vol. 3, pt. 1, 1878, p. 918.

CAT CREEK COAL (NO. 5).

Position.—The lowest workable coal in the Allegheny formation in the Big Sandy Valley district occurs below the Vanport limestone. This coal usually lies directly on, or a very few feet above, the Homewood sandstone. Where the two sections given on pages 41–42 were measured, it may be below the lowest member shown and hence not appear in the section. This coal is regarded as the equivalent of the main workable bed on the headwaters of Cat Creek, and as it probably attains its maximum development in that region and is generally known in this part of Kentucky as the Cat Creek bed, it will be called in this report the Cat Creek coal. Crandall, in his general section of this part of Kentucky, has placed No. 5 coal, to which he gives the names Cooksey Fork and Pennington coal,[a] as the first below the horizon of the Vanport limestone, and therefore it appears probable that Crandall's No. 5 or Cooksey Fork coal is the same as the Cat Creek bed of this report. Crandall states that this coal occurs 30 to 40 feet below the limestone ore, referring to the ore associated with the Vanport limestone. This distance is rather large for the region about the head of Cat Creek.

Extent and development.—About Louisa the presence of this coal is nearly always indicated by a bloom. Its position above the Homewood sandstone is best seen in the gorge of Lick Creek near its mouth and on the Lick Creek pike. About 2½ miles southwest of Louisa it has been opened by Mordecai Wilson, but the bank is now fallen shut. Near Osie coal has been dug, but the bed is reported to be thin. In West Virginia, south of Cassville, this coal is usually present, but is thin and, as on the Kentucky side, is very rarely worked. A short distance south of Louisa it is below the flood plain. In the immediate valley of Big Sandy and its tributaries to the south it will probably not prove workable over any considerable area.

This coal is the most important bed on the headwaters of Cat Creek and there and to the west on the headwaters of Cherokee Creek and Dry Fork it attains its maximum thickness in this quadrangle. Further descriptions and an analysis of it are given in connection with the mention of its occurrence on Cherokee Creek (p. 103). At the headwaters of Cat Creek it has not been developed on a commercial scale, owing to remoteness from transportation. The extent of its outcrop in this locality is limited, as the northward dips carry it below drainage level near the mouth of Thompson Fork. On the map its outcrop line in the valley of Cat Creek is practically coincident with the red line which indicates the horizon of the Vanport limestone and its clay. It has been opened by Andrew

[a] Report on the eastern coal field: Kentucky Geol. Survey, vol. C, p. 19, 1884, pl. 1.

bb, Andrew Cooksey, and W. H. Moore, and at Moore's bank the lowing section was measured:

Section of Cat Creek coal bed at bank of W. H. Moore.

	Inches.
Shale, black.	
Coal	1½
Bone	4½
Coal	17½
Bone	½
Coal	24
	48

thickness of 4 feet 10 inches to 5 feet is reported from other ntry banks in the immediate vicinity. In some places, at least, s coal is sufficiently thick and free from impurities to make it uable, but in other places it is so badly split up by impure parts that it will have little value except for country trade. The lowing two sections illustrate this impure phase:

Sections of Cat Creek coal bed.

	Inches.
Shale, black, containing small stringers of coal	1
Coal	1½
Shale, black	4
Coal	5
Shale, black	12
Coal and shale	4
Coal	4½
Bone	1
Coal	9
	42

Shale, black.	
Coal	4
Shale, black	19
Coal	2
Bone	1
Coal	1
Bone	½
Coal	8
Bone or coal	½
Coal	1½
Clay.	
	37½

The fact that it has a good section on Cat Creek and shows well Cherokee Creek is sufficient evidence that this coal bed is well rth careful attention. It should be prospected with a diamond drill the intermediate territory before actual operations on it are begun.

Character.—The Cat Creek coal is of excellent quality and when not badly split up gives much satisfaction as a domestic fuel, being hauled many miles into the surrounding country.

POTTSVILLE COALS.

LICK CREEK (NO. 4).

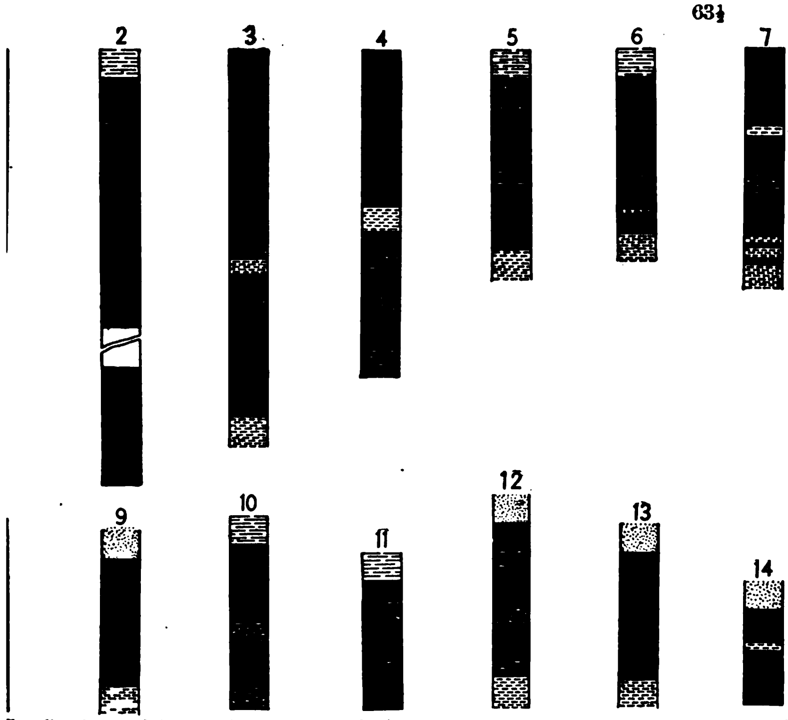
Extent and development.—The highest coal in the Pottsville is from 55 to 75 feet above the Torchlight bed. It is locally known as the "5-foot vein" but is sometimes called the "Big vein" and probably corresponds with coal No. 4 of the Kentucky Survey. Its maximum development is in the hills east of Lick Creek and between Lick Creek and Levisa Fork, and it may be conveniently designated, therefore, the Lick Creek coal. From the fact that it overlies the Torchlight bed it occurs over a smaller territory above drainage level, and is not found as far south in the hills as the Torchlight. Though locally thicker than the coal below, it will probably not be found so persistent and uniform. It has been prospected by the Torchlight Coal Company between Threemile Creek and Levisa Fork, where it proves to be of workable thickness, and in this region it is about 60 feet above the Torchlight bed. East of Threemile Creek, prospects have been opened on it on Donithon Branch, where it is also workable. In West Virginia the coal at this horizon does not appear to be of workable thickness; at least no openings were observed on it. West of Lick Creek the horizon is marked by a coal bloom or smut, but in no place has it been found sufficiently thick to work profitably except for local purposes. It has been worked for family use at one or two points on San Branch near Irad and also one-fourth of a mile below the point where Little Blaine Creek enters Big Blaine. So far as known the coal has never been worked on a commercial scale in Big Sandy Valley. In this district the most promising field in which to prospect for this coal is in the hills along Levisa and Tug forks, south of Torchlight.

Character.—Sections obtained from this bed are shown in fig. 5. The section obtained at the head of Lower Gavitt Creek on the property of the Torchlight Coal Company differs strikingly from the remaining three, obtained from test drifts of the Louisa Coal Company in the hills between Lick Creek and Levisa Fork, just west of Torchlight. The upper 20 inches of the coal on Lower Gavitt Creek appear to be much broken up. The lower benches, which average about 19 or 20 inches, are separated by a small clay parting. In places the upper bench consists of clean coal, giving the three benches as in the Torchlight bed. The coal is also reported with three benches on the headwaters of Donithon Creek, but here the upper bench is slightly thicker than either of the two lower. The section

sured by C. M. Weld for the Torchlight Coal Company shows character as follows:

ction of Lick Creek coal bed at the head of Ox Hollow, Donithon Creek.

	Inches.
Coal	25½
Parting	5½
Coal	18
Parting	2½
Coal	12
	63½



5.—Sections of higher Pottsville coals in Big Sandy Valley district. Lick Creek l (Kentucky No. 4): 1, Torchlight Coal Company, Lower Gavitt Creek; 2, 3, 4, ilsa Coal Company, between Lick Creek and Levisa Fork. Torchlight coal (Kenky No. 3): 5, Torchlight Coal Company, head of Lower Gavitt Creek; 6, mine of chlight Coal Company; 7, Threemile Creek; 8, Andrew New, opposite (west of) chlight; 9, opening north of No. 8; 10, Henry Cochrane, Lick Creek; 11, Left Fork tle Blaine Creek; 12, Right Fork Little Blaine Creek; 13, Kelly Frailey, Right Fork tle Blaine Creek; 14, Andrew Hayes, Right Fork Little Blaine Creek. Scale, 1 h=5 feet.

the hills along Threemile Creek this coal will probably average een 3 and 4 feet.

est of Levisa Fork, on the property of the Louisa Coal Company, coal thickens, as will be seen from fig. 5, sections 2, 3, and 4. In ral the coal in this vicinity is irregular, but consists, where ob-d, of two main benches separated by a clay parting varying a few inches to 5 feet. The coal south of the prospect pits of company is reputed to be very irregular and of poor quality, but statements can not be corroborated by the writer, as nothing was

seen of it at any point. West of Lick Creek, about one-half mile above the mouth of Rhubens Branch, the coal measures about 2 feet on the outcrop in a well-exposed section showing the top of the Pottsville and the Allegheny, as follows:

Section on Rhubens Branch.

	Ft.	In.
Hilltop.		
Shale, red	30	
Sandstone	20	
Shale, red	20-25	
Bench.		
Sandstone, shaly	18	
Shale, sandy	16	
Sandstone, shaly	6	
Shale, light olive	7	
Clay, white	1	
Soil, ferruginous clayey	30	
Shale, sandy	9	
Sandstone, coarse, yellow, massive	15	
Shale	10	
Clay	5	
Shale	5	
Clay with iron-ore nodules	5	
Shale, black (coal?)		2-3
Shale, gray	10	
Coal		2
Shale, drab	7	
Shale, purple	5	
Sandstone	8	
Coal No. 5		12
Sandstone, laminated	15	
Coal No. 4 (Lick Creek coal)		24
Sandstone, massive	25±	
Coal No. 3.		
Sandstone, massive.		

This section indicates the erratic character of the Allegheny and shows how difficult it is to locate its exact upper boundary.

The massive sandstone at Busseyville marks the top of the Pottsville formation. This sandstone rises in the direction of the forks of Little Blaine Creek, and a short distance below the residence of L. Pigg the coal appears above drainage level and has been opened about 15 feet above the road to the left. A short distance beyond the same coal shows a section as follows at F. R. Bussey's bank:

Section of coal bed at F. R. Bussey's bank, near Busseyville.

	Inches.
Sandstone, massive.	
Coal and black shale	30
Sandstone lentils, sometimes absent	2
Shale and bone	10
Coal	5
Shale, drab fissile	22
Coal	15
Bone	1

	Inches.
Coal	2
Bone	2
Coal	15+

About 60 feet below this coal, at road level, is the bloom of another and lower coal, which has been opened by L. D. Pigg in the hill to the west. This coal has a section as follows:

Section of coal bed opened by L. D. Pigg near Busseyville.

	Inches.
Limonite, nodular	4
Shale	19
Bone	3
Coal	4
Shale	19
Bone	4
Coal	7

These coals are believed to be above the true Torchlight coal, which shows as a bloom at the road corner at the confluence of Left and Right forks of Little Blaine Creek. It is possible that one of these two beds represents the Lick Creek coal and that the other may represent a new bed in the section. It is also possible that these coals may represent the two benches of the Lick Creek coal, the parting of 5 feet of clay in the region east of Lick Creek having expanded to 60 feet farther west. The data on this point are not sufficient to make it absolutely certain that these two beds represent the two benches of the Lick Creek bed, but the writer is inclined to this view. Neither of the two coals, where seen outcropping, is of commercial importance.

Where the Lick Creek coal is of workable thickness it is of a bright, hard, bituminous variety, with occasional bands of splint or semi-cannel coal. The upper of the two lower benches appears to be the more uniform, but in places the lower may probably be worked with it. Locally, however, it is badly split by bony partings. At many points between Levisa Fork and Tug Fork all three benches may be worked if sufficient care is exercised in separating the clay and bone partings. As a rule the roof of this coal is formed by shale, but in some places the base of the massive Homewood sandstone extends down practically to its top. The following analyses indicate the character of this coal:

Analyses of Lick Creek coal.

	1.	2.
Moisture	6.00	0.97
Volatile matter	32.40	32.70
Fixed carbon	57.40	55.69
Ash	4.20	9.58
Sulphur	.049	1.05

1. Furnished by J. H. Northup, of Louisa, Ky., from a sample collected at the head of Donithon Creek.
2. Furnished by A. C. Collins, of the Louisa Coal Company. Otto Wuth, analyst. Sulphur is included in the total.

The foregoing analyses show a good coal of the bituminous grade, corresponding favorably with much of the Pittsburg coal of western Pennsylvania. It contains a rather higher percentage of volatile matter and correspondingly lower fixed carbon. On account of its hard and somewhat splinty character it will bear transportation and stocking well. It is doubtful whether it will prove to be a good coking coal, but experiments with regard to this point have not been made.

TORCHLIGHT COAL (NO. 3).

Name.—The next lower workable coal in the Pottsville group is perhaps the most important of all the beds thus far developed on the upper waters of Big Sandy River and its tributaries in this quadrangle. In the Kentucky reports this coal is known as No. 3, or McHenry coal, the latter being the name of the property on which the coal was first worked on any marked scale. In this description it will be referred to as the Torchlight bed, from the fact that the Torchlight Coal Company has worked it more extensively than any other company at Torchlight, on the Chesapeake and Ohio Railway 6 miles south of Louisa, and opposite the old McHenry property on the west side of Levisa Fork. It is locally known also as the "Check House vein." It corresponds to the Lower Mercer coal of Pennsylvania.

Extent.—The Torchlight coal first appears above drainage level on Threemile Creek near the Threemile schoolhouse, and is reported on Levisa Fork near the bed of the creek just north of the railroad bridge at Walbridge. It is probably present in all the hills south of these points in the territory included between Tug and Levisa forks and also in West Virginia. East of Threemile Creek, however, it does not seem to have been extensively prospected and little seems to be known about it. In the hills between Threemile Creek and Levisa Fork it has been fairly well prospected, and this is also true of the territory lying between Levisa Fork and Lick Creek to the west. It is present in the hills along Left and Right forks of Little Blaine Creek, but owing to northward dips disappears below drainage level a short distance north of the confluence of these two forks. A reference to the map (Pl. I) will show the outcrop of this bed so far as it is known to be of workable thickness.

Development.—This coal was first opened at McHenry's bank, on the west side of Levisa Fork opposite Torchlight. Since then it has been developed on a commercial scale by the Torchlight Coal Company at Torchlight. During the summer of 1905 the mine was closed, but it started up again in the following spring. In the hills west of Levisa Fork this coal has been faced in several places by the Louisa Coal Company to ascertain its possibilities. It has also

been opened by Andrew New and others northwest of Torchlight. On Lick Creek several small country banks have been opened and a small amount of coal has been removed for the country trade by Richard Childers, Henry Cochrane, and others. On Left Fork of Little Blaine Creek this coal appears to have a section similar to that in the region about Torchlight. It has been opened at a few places along this creek a short distance south of its confluence with Right Fork.

Along the pike east of Adams it is found well up in the hills on the south side of the creek and near road level on the north side, owing to the steep dips. It has been opened in this region by Kelly Frailey, Andy Hayes, and others. It is possible that the coal opened by James Adams west of Adams corresponds to the Torchlight bed.

Character.—Ten sections of the Torchlight coal are represented in fig. 5. It will be seen from these sections that the coal bed is somewhat variable. In places it occurs as a single bench, as at the bank of Richard Childers, on Lick Creek, where 37 inches of clean coal were measured, but usually it consists of two or three benches. As a rule a clay parting separates the top benches. This clay parting is in general of knife-edge thinness (sections 5, 6, 8, 9, 11, fig. 5), and is, perhaps, entirely cut out in some places, as at the Henry Cochrane and Kelly Frailey banks (sections 10, 13, fig. 5), on Right Fork of Little Blaine Creek. It rarely attains a thickness of an inch, though in exceptional cases it may exceed this measurement, as at an opening of the Torchlight Coal Company on Threemile Creek, where a parting of 3 inches was measured (section 7, fig. 5). The third or lowest bench ranges from less than 6½ to over 14 inches in thickness. It is separated from the middle bench by a persistent bone parting averaging 3 to 4 inches.

The coal in this bed is of both the splinty and the soft bituminous varieties. The top bench above the clay parting is usually soft; the middle bench, though generally of soft, lustrous bituminous coal, in many places contains hard, splinty layers and is therefore slightly harder. The lowest bench is as a rule of hard, dull, splinty coal, and serves as an excellent base for pillars in mine working. This bench is also drilled before shooting. In mining, all three benches may be worked and the bone or "niggerhead" between the two lower benches removed by hand picking. The roof of the coal bed varies. It is in some places shale and in others massive sandstone. The shale, where present, ranges in thickness from a few feet up to 15 feet, more or less, and sometimes gives much trouble in mining. The roof of the coal, where it is composed of shale, has to be carefully watched and rather heavily timbered to avoid falling and "creeping." On this account mining with a shale roof is attended with more danger and expense than where the coal is overlain by sand-

stone. Above the layer of shale there is usually a very massive sandstone of varying thickness, which serves as one means of identifying this bed.

Below the lowermost worked bench there are in many places one or two smaller benches of coal separated from the main bed by a fire clay or bone parting (sections 6 and 7, fig. 5). These are never mined. The true floor of the coal, as a rule, is clay. A few analyses of this coal are as follows:

Analyses of Torchlight coal.

	1.	2.	3.	4.	5.
Moisture	4.60	2.88	2.10	1.90	1.28
Volatile matter	35.70	37.40	35.95	35.47	35.25
Fixed carbon	53.28	40.85	37.79	35.86	55.37
Ash	6.42	18.80	24.16	26.27	8.40
Sulphur	1.08	1.11	1.77	1.22	1.18

1. Sample from McHenry's coal bank, Lawrence County, Ky. Report on the eastern coal field: Kentucky Geol. Survey, vol. C, p. 18. Robert Peter and Mr. Talbut, analysts.
2. Torchlight Coal Company's mine, second entry. Ricketts & Banks, analysts.
3. Torchlight Coal Company's property on Lower Gavitt Creek. Ricketts & Banks, analysts.
4. Torchlight Coal Company, Fivemile Shoal. Ricketts & Banks, analysts.
5. Crop coal from hill between Levisa Fork and Lick Creek property of the Louisa Coal Company. Otto Wuth, analyst. Sulphur is included in the total.

From these analyses it will be seen that the volatile matter averages about 35 per cent and the fixed carbon approximately 45 per cent. The ash and sulphur are comparatively high, especially in the samples analyzed by Ricketts & Banks for the Torchlight Coal Company. The lower and dirty benches were probably included in the samples analyzed by this firm, but in the mining of the three upper benches this material would probably serve as a floor; or, if it were found necessary to remove it, it could be picked out and gobbed, and the main and clean benches shot down from above. The main benches would yield from 2½ to 4 feet of fairly clean coal; on an average, perhaps about 3 feet. With this figure as an average, the yield per acre may be conservatively placed at 3,500 tons. From the sections of the coal given in fig. 5, it will be seen that the danger of introducing unduly large amounts of ash into this coal during the course of actual mining is very great, and the amounts of ash represented in analyses 1 and 5 are perhaps below what would be found in practice. If the entire bed—that is, the three main top benches—is to be mined and successfully marketed, pains must be taken to eliminate the bone and clay where they are of abnormal thickness. This may be accomplished either by hand picking—a slow, tedious method and one which in the hands of miners is liable to lead to injury both to the reputation of the company and to the coal—or by washing. The expense of the latter operation ought not to exceed from 5 to 7 cents per resulting ton of coal. In no case would it appear advisable to mine any coal below the lower split ...d.

LOWER COALS.

Extent.—The lowest coals developed in this district are those arest its southern edge, as the rise of the beds to the south brings successively lower horizons toward the southern edge of the quad-ıgle. Certainly the lowest exposed coal beds in the entire quad-ıgle occur in the section southwest of Gallup. As will be seen from section of the Pottsville formation on pages 38–39, and from sections on Pl. IV (p. 28), four small coals are found below the aron sandstone. None of these coals has ever been worked in this ıdrangle, though one of them measures 24 inches at one point. tween the Sharon and the next massive sandstone above is about feet of shale with two small coal beds. The highest of these ıls has been worked near a sharp bend in the railroad track south Torchlight. Where measured on the outcrop this coal is 16 hes thick. The sandstone above it was formerly, though prob-ly erroneously, correlated with the Sharon sandstone seen on Ever-ın Creek. About 2 miles south of Torchlight there is at this hori-n 100 feet of almost continuous sandy beds with two slight breaks ar the middle. Above this massive member are several small coal ds in an interval of 30 to 35 feet. A detailed section of this group of als, measured near the mouth of Lower Gavitt Creek, below Torch-ght, is as follows:

Section of coals at the mouth of Lower Gavitt Creek, Lawrence County, Ky.

	Ft.	In.
Shale, black, and clay	2	2
Coal } "Little Cannel"	1	7
Parting } "Little Cannel"		½
Coal } "Little Cannel"		2
Sandstone, laminated	10	
Coal	1	
Shale, sandy, or fire clay	2–3	8
Coal	2	5
Shale	2	5
Coal		3
Shale, drab to dark	2	
Coal	1	8
Shale, black, and fire clay	2	3
Slate, black, and bone.		
Fire clay	3	
Bed of creek.		

The uppermost of these coals is workable over a considerable area the southeast corner of the quadrangle and may be looked for at a tance of about 140 feet below the Torchlight coal. It is present the hills along Levisa Fork and Threemile Creek, gradually rising

from railroad level at the mouth of Lower Gavitt Creek, just below Torchlight station. West of Levisa Fork this coal appears above drainage level near the head of Lick Creek, the group of coal blooms in which the "Little Cannel" belongs appearing near the summit of the ridge in the road at the head of Lick Creek. The character of the coal in this vicinity could not be determined, owing to the fact that it has not been opened, but west of the Left Fork of Little Blaine it has been opened in a few places near the level of the creek and is of workable thickness, though badly split up by bone and fire-clay partings.

On Right Fork of Little Blaine the lithologic succession is not so characteristic as to the eastward. Near Adams a massive sandstone appears above the bed of the creek and rises gradually to the south up the creek. On the hill southeast of Adams a distinct coal blossom may be seen close to the top of this sandstone with the shale above it. The sandstone underlying this coal may be traced with hardly a break up the creek, and about three-fourths of a mile south of Adams the coal directly above it is worked. Instead of being overlain by shale, as at Adams, it is now capped by a very massive sandstone, and the coal, as nearly as can be estimated, is about 110 feet below the Torchlight bed, and is regarded tentatively as of the "Little Cannel" group, though it may be higher.

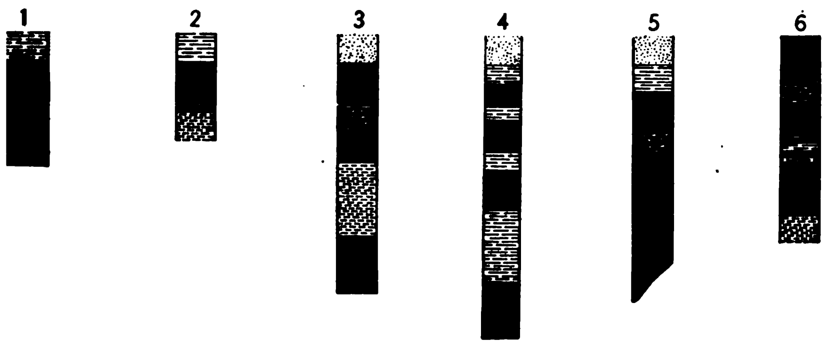
Development.—The "Little Cannel" coal has been opened near the head of Threemile Creek and at one time was mined and shipped from this locality over the old Chatteroi Railroad. About 5,000 tons are reported to have been shipped before the road's alignment was changed to its present location along Levisa Fork. Operations ceased as a result of the financial panic in 1893, and since then nothing on a commercial scale has been attempted.

A short distance south of Torchlight the coal has been worked on a small scale and a few hundred tons have been removed, under lease from the Torchlight Coal Company. There are small openings north of the station and in the hills on the west side of the fork. Developments on Left and Right forks of Little Blaine Creek are of local importance only and supply the country trade. Though this coal is above drainage level along the headwaters of Rich Creek, it does not seem to be of sufficient thickness to justify opening it on even a small scale.

Character.—This bed of coal is known as the "Little Cannel" bed about Torchlight for the reason that it contains near the middle of its upper bench a thin band of coal with enough volatile matter to place it among the cannel coals. Sections obtained near Torchlight (sections 1 and 2, fig. 6) show this coal to vary from a thickness of 19½ inches north of the tipple to 2 or 2½ feet south of the tipple of the Torchlight Coal Company. This coal is split into two benches with a part-

ıg of one-half to 1 inch of clay near the bottom. The cannel layer is ot shown in the sections given in fig. 6, but occurs near the middle f the upper bench and ranges from 3 to 6 inches in thickness. It ›sembles splint coal rather than true cannel. Perhaps the chief value f this bed in the future will result from this band of cannel. Four ches of cannel to 2 feet of coal may be taken as a conservative aver- ;e of the two grades of coal in this bed. On this basis it comprises ıe-sixth of the total coal and would yield about 483 tons per acre, suming the specific gravity of 1.194 determined by Mr. Hislop. It parates fairly readily from the bituminous coal above and below ıd breaks out in large blocks.

The coal, as a whole, is moderately lustrous, with yellowish brown reaks. The cleavage is laminated with cross fracture, angular to



ɢ. 6.—Sections of lower Pottsville coals in Big Sandy district. 1, "Little Cannel" coal, north of Torchlight; 2, "Little Cannel" coal, south of Torchlight; 3, Hiram Blackburn, Left Fork Little Blaine Creek; 4, John R. Pack, Right Fork Little Blaine Creek; 5, Mary Hayes, Right Fork Little Blaine Creek; 6, E. G. McInster, Right Fork Little Blaine Creek. Scale, 1 inch = 5 feet.

ıbconchoidal. On the fire it intumesces and agglomerates. Analyses ·e as follows:

Analyses of "Little Cannel" coal from Levisa Fork.

	1.	2.
'ater	2.25	2.70
olatile matter	54.95	45.61
'ixed carbon	39.85	47.17
sh	2.95	3.90
ulphur	.50	.62

1. Department of mines and metallurgy, World's Columbian Exposition, analyst.
2. George R. Hislop, Paisley Gas Works, analyst.

George R. Hislop, of the Paisley Gas Works, who has made a ather exhaustive test of this coal and has also studied the resulting ases, reports that "this is an excellent cannel coal. It is easily dis- illed, yields a large volume of 34.20 candle gas, and affords at the

same time 10.25 hundredweight per ton of excellent residual coke. The foul gas contains a moderate percentage of impurities. Compared with main Lesmahagow cannel coal taken as 100, calculated on the basis of 13,000 cubic feet of gas and 1,535.5 pounds of sperm per ton, and having regard for the secondary products and the cost of purification of the gas, this coal is equal to 107.48."[a]

TRANSPORTATION FACILITIES.

Transportation facilities in the Big Sandy Valley district are furnished at present by the Chesapeake and Ohio Railway along Levisa Fork in Kentucky and by the recently completed Norfolk and Western Railway along Tug Fork in West Virginia. The line of the Chesapeake and Ohio Railway was formerly up Threemile Creek after crossing Levisa Fork at Walbridge, and the roadbed of this old line, from which the steel was removed about fifteen years ago, is still in fair condition for a spur track from the main line at Walbridge, should the developments on Threemile Creek warrant its construction. In addition much of the Big Sandy region is readily accessible by water. The improvements along the river projected by the Federal Government, which are now partly completed, are expected to provide navigable depths many miles south of the limits of this quadrangle and to provide a navigable season through the entire year instead of six months, which is now the average. The facilities for cheap transportation that will be offered when these improvements are completed are so obvious as to need no comment here.[b]

CHESAPEAKE AND OHIO RAILWAY DISTRICT.

EXTENT.

The district tributary to the Chesapeake and Ohio Railway includes nearly the whole of Boyd County, together with small parts of Greenup, Carter, and Lawrence counties, Ky. Its eastern boundary has already been described as the ridge separating the waters of Big Sandy and East Fork. The ridge separating the waters of Little Sandy River and East Fork of Little Sandy has been chosen as its western boundary. On the south it is limited by the ridge south of Straight Creek and the headwaters of East Fork. This district includes all the operations along the Ashland Coal and Iron Railway as far south as Straight Creek.

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[a] Compare other cannel coals on pp. 88–92.

[b] See Survey of Big Sandy River, West Virginia and Kentucky, including Levisa and Tug Forks: House Doc. No. 326, 56th Cong., 1st sess.

GEOLOGY.

The rocks in this district are comprised in the Pottsville, Alleıeny, and Conemaugh formations. The highest beds belong to ıe Conemaugh. This formation is not represented in its entirety any point west of Big Sandy River, so far as known. The eastard dips which cause the lower beds to cover most of the surface est of the Ashland Coal and Iron Railway bring the Conemaugh ds lower and lower in the hills toward Big Sandy River. They e the only surface rocks in the southeastern part of this district, ıere they have a thickness of 300 to 400 feet. At the base of this rmation is a rather massive sandstone, well shown west of Alley the hills bordering Pigeonroost Creek. Above the sandstone, at rying distances, but rarely exceeding 40 feet and usually less, curs a fossiliferous limestone, one of the Cambridge beds, which closely overlain by another massive sandstone. Thus the lower ndred feet of the formation is usually sandy and is accordingly mparable with the lower part of the Conemaugh at the mouth Big Sandy River. Though here and there the upper part of the rmation contains massive sandstone, it is shaly for the most part, e shales being reddish and purplish, with local green layers. Many these shaly members would be of value were they situated near ıes of transportation. No commercial coals are known in this rmation.

The Allegheny formation in this district has a thickness aver-ging from nearly 180 to 200 feet. The general section (Pl. IV, 28) illustrates well the number and relations of the coal and clay ds in this formation. About Ashland its basal portion is very ndy and comparable with the lower part of the Allegheny in Ohio. See section, pp. 30–31.) Farther south the massive phase of the ndstone, at least above the Winslow coal bed, seems to change to a ore thinly bedded or shaly sandstone, the remainder of the interval etween the Winslow and Coalton coals being shaly. The Coalton oal is usually overlain by a massive sandstone above which is a thin ed or purple shale bed, well exposed on the county road east of ummit. From the top of the sandstone overlying the Coalton coal the base of the Mahoning sandstone the beds are prevailingly shaly ı character, and include the Hatcher and Zelda coal beds.

The materials of most economic importance in this group of rocks re coal, fire clay, and iron ore. In most places the valuable coal beds re confined to the lower half of the formation, but in a few localities ıe higher coals are workable. Not more than three distinct workble coal beds were seen, and in most places only two coals are of orkable thickness. A valuable bed of fire clay occurs well toward he base of the formation associated with the Vanport ("Hanging

Rock ") limestone, and this limestone is overlain in many places by a bed of iron ore, which in the early seventies was greatly esteemed and extensively mined by stripping. Between the Winslow and Coalton coal beds, about 20 to 25 feet above the latter, is found a kidney iron ore which about thirty years ago was worked to some extent, and about 25 feet above the Coalton coal is another horizon of kidney ore.

In a general way the rocks of this formation cover the surface of the district in a zone conforming in trend with the structure contours—that is, northeast and southwest. West of the Ashland Coal and Iron Railway the Allegheny is present in the tops of the hills, but east of the railroad the dips cause the formation to occupy a lower and lower position in the hills and to disappear well up toward the head of East Fork and Straight Creek. In the northwestern part of the district they cover most of the surface, but in the southeastern part they are entirely below drainage level.

The lowest beds in this district are exposed along East Fork of Little Sandy River, in the northwestern part of the district. Here are Pottsville rocks at least 260 feet thick. To the east, approaching the center of the basin, the Pottsville gradually descends below drainage level, and except along Ohio River the territory covered by it east of the Ashland Coal and Iron Railway is very small. West of the Ashland Coal and Iron Railway, in the hills dividing Little Sandy from East Fork the Pottsville reaches well up to the hilltops, and its rocks are conspicuous on the surface. The formation is prevailingly sandy, but perhaps not quite so much as in the region along Tug and Levisa forks. The top member, the Homewood sandstone, maintains its usual prominence in most parts of this district. Along Ohio River near Ashland, and to the southeast, near Cliffside Park, this member is unusually massive, attaining in some places a thickness of 75 feet. It is a question whether all this sandstone is really of Homewood age, for west of Ashland it apparently forms one massive cliff reaching to the base of the fire clay at the horizon of the Vanport ("Hanging Rock") limestone. It is quite possible, therefore, that the upper part of this member may be of Allegheny and not Pottsville age. Though the Homewood sandstone in this district is generally massive, south of Princess and near Coalton and Rush it dwindles to a shaly sandstone, never exceeding and rarely reaching a thickness of 10 feet. Taken as a whole, it is, however, the most prominent bed in the Pottsville in this district. The underlying beds are prevailingly sandy, chiefly sandy shales and shaly sandstones, becoming in places prominent cliff makers.

The number of coal beds in these rocks is not definitely known. It is probable that there are more than have heretofore been recognized. Near Princess tunnel, for instance, a section was measured from the road corner near the store of the Princess Land and Mining Company

the highest exposed rock above the tunnel, and in this section four al beds showed within a distance of 70 feet below the top of the omewood sandstone. On the road ascending the hill, a few rods rthwest, G. H. Ashley measured another section to the top of the ll, which showed the coal beds at the top of the Pottsville and also me of those in the Allegheny. This section is as follows:

Section near Princess tunnel.

Top of hill.	Ft.	In.
Sandstone, shaly	8	
Sandstone, shaly, calcareous	2	
Shale, olive	6	
Sandstone, hard	2	
Shale, olive	6	
Streak of dark shale.		
Clay, drab	2	
Iron ore	1	
Shale, olive	6	
Coal (No. 8)		2+
Clay, light drab	2	
Shale, olive, and sandstone	12	
Shale, olive	12	
Iron-ore nodules		8
Clay, drab, or shale	4	
Sandstone, olive, shaly	7	
Coal (No. 7)	1	3
Shale, drab	3	
Shale, sandy, and shaly sandstone	15	
Iron ore, red		6
Shale, olive	5	
Sandstone, hard massive	15	
Coal	1	9
Clay, drab	3	
Coal		½
Clay, drab flint		6
Clay, black carbonaceous flint		0-2
Clay, light drab, sandy at base	7	
Sandstone, green and white, fine-grained (Homewood—top of Pottsville)	8	
Shale, olive, and fire clay	4	
Iron ore		6
Shale, drab	6	
Coal		5
Clay		2
Coal		5
Clay, light drab	3	
Shale, dark drab		6
Clay, dark drab to black	1	
Clay, drab	2	
Sandstone, thin-bedded, shaly	12	
Shale, sandy	5	
Coal		1½

	Ft.	In.
Shale, reddish brown		1-4
Coal		2
Flinty lentil		0-2
Coal	1	
Clay		9
Coal		6
Fire clay, light drab, sandy	4	
Coal		5
Clay		1
Coal		3
Shale, sandy and drab fire clay	6	
Shale, sandy	12	
Sandstone	15	

The following section, compiled from barometric measurements along the northern edge of the area from Argillite eastward to Hood Creek, gives a general idea of the character of the Pottsville rocks and shows also the position of the workable coals:

Section from Argillite to Hood Creek.

	Ft.	In.
Sandstone, Homewood	30	
Coal, workable in places.		
Sandstone, shaly	20-40	
Coal.		
Sandstone	6	
Coal		2-3
Sandstone	6	
Coal (No. 3), workable in places.		
Sandstone, massive	10	
Concealed	15±	
Coal		5
Fire clay	4	8
Shale and massive sandstone	35	
Coal, workable.		
Probably sandy	50	
Coal		4
Sandstone, shaly	20	
Concealed	10	
Shale, black, and fire clay	10	
Concealed	10±	
Sandstone, massive	10	
Concealed	10±	
Sandstone, massive	10	

On Catletts Creek and in the eastern part of Ashland there is an important bed of fire clay underlying the Homewood sandstone. Formerly the iron ore in this formation in this district was of considerable economic importance, notably the bed occurring 30 to 40 feet above the Danleyton coal, called by P. N. Moore "the main block ore."[a] None of the beds of iron ore of this formation are now worked

[a] Report on the eastern coal field: Kentucky Geol. Survey, vol. C, 1884, pp. 133-138.

THE COALS.

ALLEGHENY COALS.

UPPER COALS.

The highest coal bed that has been worked in this district corresponds with coal No. 9 or the Upper Freeport coal of the Ohio section and with the Zelda coal in the Big Sandy Valley. It is not of sufficient thickness to be of any practical importance. It has been opened by Albert Baldridge near the mouth of Garner Creek and is reported to be 18 to 20 inches thick. In the road 20 feet below is the bloom of a lower bed, probably the Hatcher coal, which is not of workable thickness here.

COALTON COAL (NO. 7).

Name.—The highest important bed in this district is the Coalton coal, or No. 7 of the Kentucky reports, known also as the Sheridan and as the Ashland[a] coal, though the latter term is not used much in northeastern Kentucky. In southern Ohio this is considered the most important of all the coal beds and is known under a variety of names, according to the location where it is developed, and shows a commercial thickness. Its most common names are derived from the mining centers Nelsonville and Straitsville, along the Marietta and Cincinnati Railroad. It is also known as the Carbondale or Mineral City coal, and in Gallia and Lawrence counties the name Sheridan is applied. The name Coalton will be used in this report, for it was mined originally at Coalton and was widely known under the name of Coalton coal.

Geologic position.—The Coalton coal lies at about the middle of the Allegheny formation. As it is the highest workable coal in nearly all of the district under consideration, no great difficulty should be experienced in identifying it. It lies in most places about 35 to 45 feet above the next lower bed, the Winslow coal or No. 6 of the Kentucky Survey, and from 40 to 60 feet below the next higher or Hatcher coal, No. 8 of the Kentucky series. It will be found about 100 feet above the top of the Homewood sandstone where the Allegheny formation is normally developed and about the same distance below the base of the Mahoning sandstone. Below it at a distance of 25 feet and above it at almost the same distance there are two persistent bands of kidney ore, the lower known as the yellow kidney and the upper as the red kidney ore. These ore beds have long been used as datum planes from which to determine the position of this coal, as they are among the most persistent and reliable ore horizons in this region.

[a] Ohio Geol. Survey, vol. 3, pt. 1, 1878, p. 918.

Extent.—The outcrop of the coal will be seen from the economic map (Pl. I). Its zone is about 10 miles wide in the northern part of the district and follows the structure lines to the southwest, gradually tapering as it approaches Willard and Webbville. The rise of the beds southward and beyond these towns soon carries this bed above the hilltops. It is present in all the hills bordering Williams Creek and its tributaries, Straight Creek, and East Fork and its branches, southeast of Naples. In the Flatwoods area south of Ashland the hills do not rise quite high enough to catch it. Though present on Catletts Creek and Keyes Creek, it is doubtful whether it is so thick as in the region farther west. Its horizon is also believed to be above drainage level on Chadwick Creek. On Garner Creek it has been opened at a few country banks.

In general the western limits of the Coalton coal outcrop coincide with the boundary between Boyd and Greenup counties, and south of Greenup County follow the divide between Little Sandy River and East Fork. The points on the various creeks where it descends below drainage level toward the center of the basin are plainly shown on Pl. I.

Development.—It may be stated that over nearly all of this district where any body of the Coalton coal is found in the hills it has either been prospected or worked. Southwest of Ashland in the hills bordering Hood Creek it is prospected 40 to 50 feet above the Winslow coal. Near Winslow and Summit it has been opened on many farms, but very few of the prospects were in good condition in the summer of 1905, while the reverse was true of the underlying Winslow. In many places the two beds had been opened on the same hillside, but the higher coal had usually been abandoned first. This fact may be explained in either of two ways. The average country bank is worked for a short time, and when the workings extend far into the hill and the expense of timbering increases, as well as the danger from the roof, the farmer, unless he has an experienced miner digging for him, will abandon his bank and open in another place. Another explanation is that the lower of the two coals immediately southwest of Ashland may be superior for domestic purposes. It is a fact that on many of the farms there is only one opening on each of these two coal beds and only the lower coal is worked. At Winslow, above the Ashland Coal and Mining Company's No. 8 mine on the Winslow coal, the upper or Coalton bed was opened but afterward abandoned. It is reported as too "pockety" to be worked with profit.

This coal bed has been opened at many points on Shope Creek near Clinton furnace. It disappears below drainage level at the point where the Catletts Creek road joins the Shope Creek road. Along East Fork of Little Sandy it has been opened on numerous

farms about Mavity and Cannonsburg. On Garner, Pigeonroost, Fourmile, and both branches of Trace Creek, and, in fact, on all the creeks flowing into East Fork, east of the Chesapeake and Ohio Railway and north of Garner and Alley, many openings have been made on this bed.

The commercial operations naturally have been confined to the territory lying close to the Chesapeake and Ohio Railway. With the exception of a little work done by the Ashland Iron and Mining Company at Winslow, now abandoned, operations on this bed begin at Princess and extend as far to the south as Willard. The names of companies working the coal at present are given on the margin of the economic map (Pl. I). With a few exceptions the operations are mostly on a small scale. The most important group of mines are those belonging to the Ashland Iron and Mining Company, situated near Rush, in both Boyd and Carter counties. Some of these are worked by the company and others are worked under lease. The Straight Creek Mining Company is another large producer, as are also the Princess Land and Mining Company, the Eastern Kentucky Railroad, John Wurts, and the Adkins Coal Company. The remaining operations are small and at the time of the writer's visit in 1905 some of them were closed. In some of the mines pillars were being drawn, indicating a nearly exhausted condition. The mines along the Chesapeake and Ohio Railway from Princess to Rush have been worked many years and large quantities of coal have been shipped. Most of the coal above drainage level and conveniently situated for exploitation has been removed, and the present operations are largely remnants of what were once very much larger and important mines. In some of the hills the coal is reported as completely exhausted.

Physical aspects.—A series of 25 sections (fig. 7) of the coal bed in this district will give a fair idea of the thickness of this bed. It will be observed that the coal occurs usually in either two or three benches, but in a few places, as at the mines of the Ashland Iron and Mining Company on Rush Creek, four benches were observed (section 10). Most of the measurements made in this district and to the southwest about Willard, Carter County, indicate that more commonly there are three benches. These benches are separated by bone or clay partings. The upper parting generally ranges from 1 to 5 inches and rarely exceeds 1 foot in thickness. In most places the lower parting is bone from one-half inch to 2 inches thick. About Rush this parting is clayey in character and thin. On Mile Branch the thin clay stratum observed above the two benches is of interest as pointing to conditions of deposition similar to those observed elsewhere, but changing after this clay was deposited, with the result that shale was laid down instead of coal.

As a general rule the upper bench is not mined. This is due to two or more causes—first, this bench is variable in thickness, and, second, it is liable to contain much sulphur and bone. The latter condi-

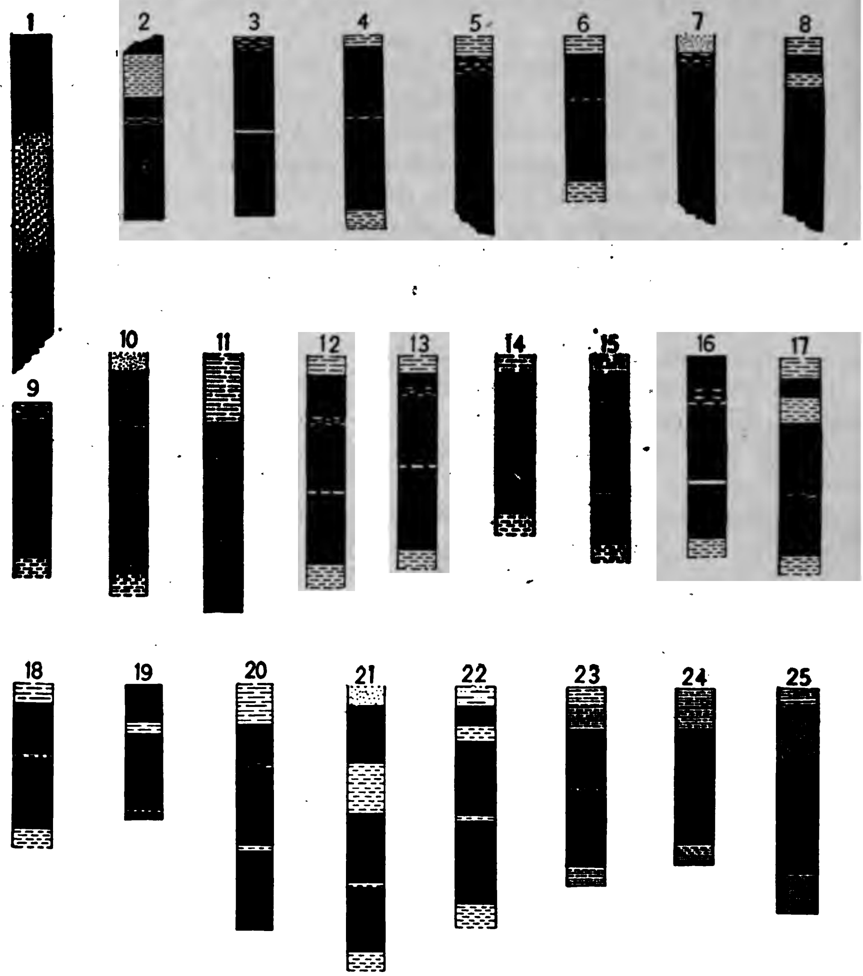

FIG. 7.—Sections of Coalton coal (Kentucky No. 7) in Chesapeake and Ohio Railway district. 1, Hills southwest of Ashland; 2, near Summit; 3, Princess Land and Mining Company, Princess; 4, Richard Jauchius, east flank of ridge between Mavity and Coalton; 5, east of Coalton; 6, Mavity; 7, 8, W. V. Sexton, head of Pigeonroost Creek; 9, James Sexton, Pigeonroost Creek; 10, Ashland Iron and Mining Company, head of Rush Creek; 11, 12, George Hull, Rush Creek; 13, John Runyon, North Fork Trace Creek; 14, Equilly Conley, west of Bellefont; 15, Straight Creek Mining Company, Straight Creek; 16, W. P. Clay, Straight Creek; 17, Morning Glory Coal Company, Grant; 18, Alex McAlvin, Cobb Fork; 19, Norton Branch Coal Company, Sandy Shoal mine (Ashley); 20, Adkins Coal Company, Rush; 21, Ashland Iron and Mining Company, No. 10; 22, Ashland Iron and Mining Company, No. 1; 23, Mile Branch, northwest of Kilgore; 24, Ashland Iron and Mining Company, No. 2; 25, Mile Branch, 1 mile northwest of Kilgore. Scale, 1 inch = 5 feet.

tion seems to prevail at the openings about Straight Creek and Denton. Though it varies greatly from point to point, it seems to be of

workable thickness in some localities, as at the George Hull mines on Rush Creek (sections 11 and 12, fig. 7). A fair thickness of the upper bench was measured in the mine of the Straight Creek Coal Company and at the opening worked by W. P. Clay about a mile farther north near the Straight Creek Coal Company's tunnel, but in this locality the upper bench is too heavily impregnated with sulphur to be marketable (sections 12, 15, and 16, fig. 7). At the Morning Glory Company's mine near Grant it is of workable thickness but so variable that little dependence can be placed on it. In this mine 26 inches of coal were measured at one point and at others it is not present. A similar condition was observed by G. H. Ashley on Mile Branch. At most of the other openings visited the upper bench is too thin to be worked. The two lower benches are almost always workable, but even this statement needs some qualification. For example, a measurement on this bed in the hills southwest of Summit gave a thickness of 6 inches to the upper of these two benches and on Mile Branch two measurements by Mr. Ashley show 1 foot of coal at two different points. Exceptional thinning was also noted in the main lower bench. as indicated by the measurements obtained at the Sandy Shoal mine near Rush, where it is only 2 inches thick (section 19, fig. 7). These exceptional figures for the two lower benches of this bed do not destroy the value of the general statement that these benches are usually of workable thickness. They are mined together, the bony parting being separated by hand. They average very close to 20 inches each, the lower being usually slightly thicker than the other. The two benches range collectively from about 3 feet 3 inches to 4 feet, a fair figure for the bed as a whole being about 3 feet 6 inches. not counting the bony parting. As much as 4 feet 9 inches of coal has been seen, though this figure must be regarded as altogether exceptional. No average minimum thickness can be given, for the coal varies from the figures given above to a mere knife-edge and in places completely pinches out. In the description of the general geology of this district a mass of sandstone was described as usually overlying the coal. As a rule it does not immediately overlie the coal, but where it does the coal suffers and at some places may be reduced to only a few inches in thickness. The operations on this bed near Coalton have long since been suspended and a measurement in the hills to the east was obtained at a small roadside bank (fig. 7, section 5). This measurement indicates a possible coalescence in the two lower or main benches. A similar condition of affairs was observed at the country banks of James and W. V. Sexton at the head of Pigeonroost Creek (fig. 7, sections 7 and 9).

The roof of a coal, though not a part of the bed itself in the strict sense of the word, is nevertheless of great importance, for on its

character may depend the margin of profit that justifies the mining of the coal. The roof of the Coalton bed is usually shale and is considered to be fairly strong. It ranges in thickness from a few inches to as many feet. In some places this shale is sandy; in others it is replaced by a massive sandstone, the coal in many such places being very thin. At the George Hull's opening near the head of Rush Creek a few feet of cannel shale were seen above the coal. The cannel shale was also observed at an opening owned by John Runyon on North Fork of Trace Creek. This shale sometimes scales off or "draws" and gives more or less trouble in the entries, but in the rooms little or no difficulty was reported from this source. The floor of the coal is apt to roll somewhat, but this is not common. Faulting is rare and where present is very slight. Small faults with a throw of 18 inches were reported near Rush at the Ashland Iron and Mining Company's opening No. 10. The superintendent of the mine reported that the largest fault known to him in the region around Rush was one near Star Furnace, with a throw of 6 feet.

Chemical aspects.—The coal itself is bituminous, but the two workable benches are not exactly alike. The upper bench is soft and lustrous and breaks into thin blocks or slabs along charcoal layers, a characteristic very common among the coals of this region. The lower bench is much harder as a rule than the upper bench and contains dull bands of splint coal. This coal is not gaseous. It is a dry-burning, noncoking coal now widely used in this part of the State for steaming and domestic purposes, and in the last three decades it has acquired an enviable reputation as an iron-making coal, being still used in the raw state for this purpose by the Ashland Iron and Mining Company at its furnace in Ashland. Its application to iron making began in 1866, when it became evident that the timber supplies which had furnished charcoal for the numerous furnaces situated in the Hanging Rock region were on the wane. Its use has continued down to the present time, naturally decreasing as many of the furnaces shut down on account of the high cost of mining the iron ore of this region as compared with the cost of Lake Superior and Alabama iron ores.

The analyses of this coal show a rather high percentage of sulphur for an iron-making coal. The coal mined along Williams Creek near Rush by the Ashland Iron and Mining Company was formerly washed and coked before using, but since the company's washer in Ashland was destroyed the coal is used raw. The ash is somewhat variable, but in the amounts of volatile combustible matter and fixed carbon the coal shows a very uniform character, as will be seen from the following seventeen analyses:

Analyses of Coalton coal from northeastern Kentucky.

	1.	2.	3.	4.	5.	6.	7.	8.
Water	4.80	5.00	4.06	4.40	3.30	7.70	6.40	6.60
Volatile combustible matter	34.20	34.50	34.24	31.10	33.30	28.16	27.22	34.36
Fixed carbon	54.90	55.40	54.70	57.90	57.60	53.04	58.88	54.64
Ash	6.10	5.10	7.00	6.60	5.80	11.10	7.50	4.40
Sulphur	1.31	1.29	1.85	2.10	2.48	1.06	.97	.72
Coke	61.00	60.50	61.70	64.50	63.40	64.14	66.38	59.04

	9.	10.	11.	12.	13.	14.	15.	16.	17.
Water	6.06	6.40	4.40	3.20	35.20	39.90	38.40	42.51	5.19
Volatile combustible matter	32.94	31.40	33.00	35.06					32.87
Fixed carbon	54.80	57.66	52.86	54.40	43.30	53.30	54.75	52.06	55.57
Ash	6.20	4.54	9.14	7.34	21.50	6.80	6.85	5.43	6.57
Sulphur	1.87	1.67	2.20	2.63	1.30	2.05	2.05	1.32	1.68
Coke	61.00	62.20	62.00	61.74	--------	--------	--------	--------	62.30

1. Average sample of coal from stock house at Ashland furnace, representing coal as actually used in the furnace. Sampled by P. N. Moore.
2–5. From rooms in mine No. 4 of Ashland Coal Company near Coalton, Boyd County, Sampled by P. N. Moore.
6–8. From the upper, middle, and lower benches of the coal bed at the old Star Furnace mines above the furnace near the mouth of Rachel Branch, west of Kilgore. The samples were taken from the pillars which had been exposed for some time and probably contained less sulphur than the freshly broken coal. Sampled by A. R. Crandall.
9 and 10. From the upper and lower benches of the coal, here consisting of but two members, at an opening on Gum Branch of Straight Creek, Mount Savage Furnace property, Carter County. These samples were selected from coal on the dump and hence are probably not so nearly representative as those taken in the mines. Sampled by P. N. Moore.
11. From the old Watson drift on Lost Creek, near Willard, Carter County. Sampled by P. N. Moore.
12. From several rooms in the mine west of Dry Fork at Willard, Carter County, main entry. Sampled by P. N. Moore.
13–16. Analyses furnished by the superintendent of the furnaces of the Ashland Iron and Mining Company at Ashland; owing to their incomplete character they are not so good as the other analyses.
17. Average of first twelve analyses.

As will be seen, most of the analyses are of coals collected by P. N. Moore and A. R. Crandall and published in the report of the Kentucky Geological Survey on the eastern coal field (vol. C, p. 181). These samples were collected by "cutting a large number of pieces of coal from the whole thickness of the bed, taking them in regular succession from top to bottom, thus representing the coal exactly as it appears at the place of sampling. Slight partings of pyritous bands, large enough to be rejected in mining, were not of course represented in the sample, but otherwise impurities were taken if they occurred at the place of cutting. Wherever possible the sample was taken from a number of rooms in each mine, or, where the coal was not opened, from as many outcrops as possible. The constant endeavor has been to secure samples representing the coal as it actually occurs in the mines." The analyses of these samples were made by Robert Peter and Mr. Talbutt, of the Kentucky Geological Survey.

Some striking facts are brought out by the foregoing figures. The main feature is the remarkable uniformity displayed over the broad area from which the samples were collected, indicating care on the part of the samplers and uniformity in the methods employed.

The average of Peter's and Talbutt's analyses is given in column 17 and shows how slightly most of the analyses deviate from the average. The figure for ash, given in analysis 6, is of interest and corroborates a statement made earlier in this bulletin as to the bony character of the topmost of the three benches. It is this bony character in conjunction with its high sulphur content that stands in the way of its exploitation even where it is of workable thickness. The content of sulphur at first sight seems rather high for an iron-making coal. If all this sulphur went into the iron it would perhaps spoil the product, but figures indicating the amount of sulphur in all the raw materials used in the charges as well as in the pig iron are necessary to indicate the way in which this constituent is distributed in the slag and pig.

The coal is not an iron-making coal through its entire extent, but only at certain localities, and even in a given mine the variation in the impurities may be such that only certain rooms or entries can be worked for furnace coal.

This bed has been regarded as the equivalent of the Hocking Valley coal of Ohio, of which Orton says[a] that "as a furnace coal it is not surpassed in the State and scarcely by any known bituminous coal." A comparison, therefore, between the Coalton coal of Kentucky and the Hocking Valley coal of Ohio and other coals which in the past have been used in the raw state in the blast furnace may have some interest. The following analyses represent coals which according to Moore have been applied for such use in Ohio, Indiana, and Illinois:

Analyses of iron-making coals from the east-central coal field.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Water	5.19	5.93	5.64	6.22	8.57	4.96	6.21	13.82	6.49
Volatile combustible matter	32.87	36.48	36.51	32.55	32.70	34.62	34.29	35.16	41.88
Fixed carbon	55.57	52.41	52.21	56.57	55.43	56.03	54.78	49.96	46.45
Ash	6.57	5.13	5.73	4.66	3.30	4.39	4.72	1.06	5.18
Sulphur	1.68	1.09	1.57	.95	.47	.62	.62	1.47	2.98

1. Average of twelve analyses of Coalton coal in northeastern Kentucky.
2. Average of ten mines of the Hocking Valley. Ohio Geol. Survey, vol. 5, 1884, p. 924. N. W. Lord, analyst.
3. Average of upper, lower, and middle benches of the Nelsonville, Ohio, bed. Ohio Geol. Survey, vol. 5, 1884, p. 975. N. W. Lord, analyst.
4. Average of eighteen samples from the great bed in the immediate valley of the Hocking and about Straitsville. Ohio Geol. Survey, vol. 3, p. 683.
5. Jackson Shaft coal, Jackson County, Ohio. Ohio Geol. Survey, vol. 5, 1884, p. 1015. N. W. Lord, analyst.
6 and 7. Lump coal from bed No. 1, Schmidgall Coal Company, Murphysboro, Jackson County, Ill. Composition and character of Illinois coals; Illinois Geol. Survey, Bull. No. 3, p. 70. S. W. Parr, analyst.
8. Brazil block coal from No. 1 shaft, Brazil Block Coal Company, Clay County, Ind. Twenty-first Ann. Rept. Indiana Dept. Geol. Nat. Res., 1896, p. 106. W. A. Noyes, analyst.
9. Brazil block coal from No. 3 shaft, Brazil Block Coal Company, Parke County, Ind. Twenty-first Ann. Rept. Indiana Dept. Geol. Nat. Res., 1896, p. 186. W. A. Noyes, analyst.

[a] Ohio Geol. Survey, vol. 5, 1884, p. 923.

These analyses of Ohio, Indiana, and Illinois coals show a fairly close agreement with the average analysis of the twelve samples of the Coalton coal of northeastern Kentucky. The figures for volatile combustible matter and fixed carbon are exceptionally close; the ash, moisture, and sulphur show considerable variation. The above analyses, taken from the various State reports, may be compared with analyses of samples collected by P. N. Moore and A. R. Crandall from the same beds in the different States mentioned. The mode of sampling was the same as that followed in the Kentucky field, and on account of this uniformity in sampling the results of the analyses given on page 71 and those which follow are really more strictly comparable:

Analyses of iron-making coals from the east-central coal field.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Water	5.19	3.26	3.74	4.40	4.54	2.62	3.44	2.40	2.70	2.68	3.46
Volatile combustible matter	32.87	33.76	36.32	35.08	29.68	32.01	31.86	35.10	36.38	36.32	36.64
Fixed carbon	55.57	54.42	55.74	55.20	57.06	58.58	59.54	55.50	55.64	53.58	53.80
Ash	6.57	8.56	4.20	5.32	8.72	6.76	5.16	9.00	5.28	7.42	6.10
Sulphur	1.68	2.247	1.299	1.659	0.758	2.472	1.370	2.373	1.664	1.803	1.848
Coke	62.30	62.98	59.94	60.52	65.78	65.34	64.70	62.50	60.92	61.00	59.90

1. Average of twelve analyses of samples of the Coalton or No. 7 coal from northeastern Kentucky.

2, 3, and 4. Hocking Valley or Nelsonville coal, from mine near Nelsonville, Ohio. 2 is from the upper, 3 from the middle, and 4 from the lower division of coal.

5. From the well-known Jackson shaft coal of Ohio.

6 and 7. From two of the best mines in the Big Muddy coal region, near Murphysboro, Ill. Large quantities of coal from both of these mines have been used in the furnaces at South St. Louis.

8, 9, and 10. Indiana block coal, from vicinity of Brazil, Ind. Samples representing the coals from three different mines. Each sample was taken from several rooms in the same mine, so as to represent the mine as fairly as possible. These mines rank among the best of that region, and coal from all of them has been successfully used in the furnace for making iron.

11. From the Sheridan mines, Lawrence County, Ohio.

2–5 and 11 sampled by A. R. Crandall; 6–10 sampled by P. N. Moore.

The results show a surprising uniformity, and though the Kentucky coal shows a higher moisture content than the other coals, yet in other respects, especially when the amount of sulphur is considered, it compares favorably with the iron-making coals of Ohio, Indiana, and Illinois.

Amount of coal.—The question of the amount of high-grade coal which is still available is of great importance. The extent of the territory above drainage level underlain by the Coalton coal can be readily seen on the economic map (Pl. I). It should be borne in mind, however, that in the region where this coal is indicated as lying above drainage level it has been largely worked out and, as has been mentioned, most of the mines now working it are nearly in a state of exhaustion. The eastern limit of the coal above drainage level is indicated on the economic map. This coal has never been exploited beyond this line by shafts. It has been mentioned (p. 46) that in the

valley of Big Sandy River its character is such that it may never become commercially available, but all over the district now under consideration it has been justly relied on as a uniform and persistent bed. Just where the coal begins to change its character from a workable to a nonworkable bed is, of course, problematical. But it is reasonable to suppose that the change to the condition observed along Big Sandy River on the south side of the basin may be gradual and that there may prove to be a very considerable body of workable coal below drainage level on the western side of the basin. Thus far prospecting with the diamond drill has not been attempted and the eastern limits of workable coal are still in doubt. The coal will have to be worked by shafting and must be approached with the plan of working up the rise—that is, to the north or to the northwest. On account of the uncertainty connected with the exact zone of change from a commercial to a noncommercial bed, it has seemed inadvisable to make an estimate of the good coal still available. It is believed, however, that the amount is large and will repay careful prospecting with the diamond drill.

WINSLOW COAL (NO. 6).

Geologic position.—The next lower workable coal in this district is known as coal No. 6 in the Kentucky reports. It is known as the "limestone coal" in the region about Ashland, Ky., from its position as the first really important bed above the Vanport ("Hanging Rock") limestone. The names Keyes Creek and River Hill coal are also applied to it. In Ohio this bed is known as the Newcastle coal[a] and is correlated with the Lower Kittanning of Pennsylvania. It is usually found about 20 feet or more above the Vanport limestone or ore, and its distance below the Coalton is from 40 to 50 feet. About midway between the two coal beds is the red kidney iron ore. These three well-known horizons should serve to readily identify this bed of coal. Near Ashland, Ky., and Coalgrove, Ohio, the rocks associated with it are massive sandstones and all over the northeastern part of the district where this coal is workable the beds both below and above it are prevailingly sandy. The conditions under which the top of the Pottsville formation was deposited seem to have continued into early Allegheny time.

Extent.—The outcrop of the coal where workable has not been indicated on the map, for the Winslow lies so close below the Coalton coal that the representations of the two would be well-nigh indistinguishable. The Winslow outcrops in the northern part of Boyd County, where it is extensively mined and used. Outside of this part of the quadrangle the coal, so far as known, is not workable

[a] Ohio Geol. Survey, vol. 5, 1884, p. 122.

over any great area. It is particularly important about the city of Ashland. Along Little Hood Creek it is present in the hills on both sides, and near Pollard, Oakview, Winslow, and Summit there are openings on nearly every farm. On account of its development about Ashland it was thought that the name "Ashland coal" might be applicable, but the next higher workable coal, or Coalton bed, is sometimes inappropriately known by that name. The name "Winslow coal" will be used in this report, as the bed is now being mined on a commercial scale at Winslow on the Chesapeake and Ohio Railway, a short distance southwest of Ashland. This bed of coal is present in all the hills between Little Hood and Catletts creeks, along Ohio River, and on Keyes Creek.

Development.—It is extensively developed in a small way in the northern part of Boyd County. In most places, however, the operations are on a small scale, most of the railroad mines apparently being closed, with the exception of mine No. 8 of the Ashland Iron and Mining Company at Winslow. About Ashland the coal is extensively mined at small banks and hauled in wagons to the city, where it supplies the local demand for fuel, and is used also by the Ashland brick plants, by the river boats, by the furnaces of the Ashland Iron and Mining Company for generating steam, and in other ways up and down Ohio River. It is highly regarded as a steaming coal and retails in Ashland and Catlettsburg at 8 or 9 cents a bushel.

Character.—The Ohio reports state[a] that coal from this bed has furnished the entire supply of Ironton for manufacturing and domestic purposes and that upon the mines of this bed all the manufacturing interests of Ironton have been built. This is very high praise for a bed of coal. The section of this bed, together with the quality of the coal around Ironton, are strictly comparable with similar features of the coal at Ashland. The two towns lie within sight of one another. The accompanying sections (fig. 8) give a fair idea of the thickness of the coal.

From the sections it will be observed that the coal usually occurs in three benches, the upper two separated generally by a thin bone parting, rarely more than 1½ inches thick. These top benches without the bone parting range in the aggregate from 2½ to 3 feet in thickness. They are separated from the lower bench by a clay or shale layer 3 to 8 inches thick. The lower bench is from 6 inches to 2 feet thick and is usually worked. The roof of the coal is sandstone, though in places between the top of the coal and the base of the overlying sandstone a few inches of dark shale is present. The sandstone locally thickens up and replaces the coal completely, and rolls of a few square feet in area are not uncommon. Some slight faults are reported. The floor of the coal is usually clay. The coal

[a] Ohio Geol. Survey, vol. 5, 1884, p. 1044.

in the upper two benches is splinty and harder than that in the lower bench, which crushes badly in the pillars. Like the other coals in the district, the upper two benches readily break into blocks or slabs 6 inches or more thick. The coal should be classed, therefore, as a semiblock coal. It is not a good coking coal, but after being washed has been made into coke by the Ashland Iron and Mining Company and used in the furnaces in Ashland. The coke is apt to be soft and spongy and contains a rather high percentage of sulphur. The results obtained, however, when mixed with a small amount of Pocahontas coke were satisfactory, and a very good coke was made by mixing it with a small amount of Kanawha coal and coking the mixture. Like all the coals in this district, it bears stocking and transportation well.

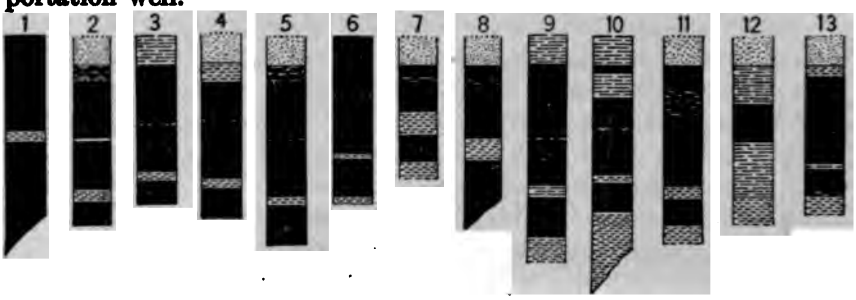

FIG. 8.—Sections of Winslow coal (Kentucky No. 6) in northern part of Boyd County. 1, 2, County road one-half mile east of Winslow; 3, Ashland Iron and Mining Company, William Wurtz, lessee, near Winslow; 4, Mrs. George McKnight, three-fourths mile north of Winslow; 5, Nancy McKnight, three-fourths mile northeast of Winslow; 6, Ashland Iron and Mining Company, No. 8, Winslow; 7, J. M. Ferguson, south of Ashland; 8, James Patten, Keyes Creek; 9, near Oakview (Ashley); 10, John Gerard, near Oakview (Ashley); 11, in hills west of Ashland; 12, Rush; 13, Newcastle coal, Ohio, section at Newcastle. Ohio Geol. Survey, vol. 5, 1884, p. 1044. Scale, 1 inch = 5 feet.

Analyses of Winslow coal.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Moisture	-------	-------	5.19	3.40	2.94	2.70	4.04	3.65	-------	-------
Volatile matter	43.52	42.95	41.86	32.30	32.50	36.70	33.60	36.59	40.17	2.97
Fixed carbon	50.54	52.10	47.69	55.40	56.70	52.60	53.34	52.62	51.49	88.26
Ash	5.94	4.95	5.26	8.90	7.74	8.00	9.00	7.11	8.34	8.77
Sulphur	1.83	2.54	1.40	1.23	1.97	1.71	1.31	1.71	1.57	1.24

1. Mine No. 12 of the Ashland Iron and Mining Company near Winslow, Ky.
2. West of Ashland.
3. Newcastle coal from tunnel mines near Ironton, Ohio. Ohio Geol. Survey, vol. 5, 1884, p. 1045. N. W. Lord, analyst.
4. Turkey Pen Hollow.
5. Keyes Creek.
6. Horse Branch.
7. Amanda furnace.
8. Average of first seven analyses.
9. Washed coal from Ashland Iron and Mining Company's No. 8 mine at Winslow.
10. Coke from No. 12.

Analyses 1, 2, 9, and 10 furnished by the Ashland Iron and Mining Company; 4, 5, 6, and 7 by Peter and Talbutt, Report on the eastern coal field: Kentucky Geol. Survey, vol. C, p. 21.

The analyses of this coal show discrepancies so great that it is difficult to say which represents the average for the region. The

analyses furnished by the Ashland Iron and Mining Company are unfortunately incomplete, but if the moisture in them is considered a part of the volatile matter some idea of the latter constituent may be had by subtracting the average moisture in these analyses where it is given from the volatile matter, in which it is apparently included. The results obtained by this process indicate a content of volatile matter between that given by Peter and Talbutt's figures and that given by Lord. Averaging these results with those given in the last five analyses, the volatile matter represented in all will average about 36.59 per cent. Other averages are given in column 8. The results are fairly characteristic of a bituminous coal of high grade. The percentages of fixed carbon and volatile matter indicate a good gas coal, but of course a coal furnishing only a second-grade coke would hardly be used for gas making. Though the coal has been washed and coked, it furnishes a nonmarketable product. Coke from this coal has never been used alone in the furnace, but always with some standard coke, like Pocahontas and Kanawha coke.

As a steam fuel the coal gives excellent satisfaction. Its average analysis, indicated in column 8, shows a very close resemblance in composition to the average analysis of the Coalton coal in this region, which is highly regarded as a steam coal. It contains less moisture than the Coalton coal, but more ash. The sulphur in the average analyses of these two coals is about the same and the volatile matter and fixed carbon in both coals are very close. In the Coalton coal the fuel ratio—that is, the quotient of the fixed carbon divided by the volatile matter—is 1.69 and in the Winslow coal this ratio is 1.43, a difference of about 0.25.

The sulphur content of the Winslow coal is rather high, but with respect to its content of moisture and the percentages of fixed carbon it compares very favorably with the good grades of bituminous coal of Ohio and Illinois. It does not rank with the best West Virginia, Pennsylvania, Kentucky, Virginia, and Arkansas coals.

Amount of coal.—This coal has been described as one of the more important beds in the southern part of Lawrence County, Ohio. It is equally important across Ohio River on the Kentucky side about Ashland. Its area of greatest development also is confined to this region. Southward about Cannonsburg and Princess this bed gradually becomes thinner, until at Rush, where the following section was obtained, the coal becomes too thin to have any commercial value whatever:

Section of Winslow coal at Rush.

	Feet.
Shale, blue, some of it light in color	1
Coal	1
Shale, black	1½
Fire clay.	

It thus appears that in the region where the Winslow coal is best developed the next overlying coal is not developed on a workable scale, and vice versa.

Coal No. 5 is reported by Crandall as having been worked near Buena Vista furnace, on Straight Creek, Boyd County, and though badly broken up by partings shows 38 to 40 inches of good coal.[a] Crandall's section at this point is as follows:

Section of No. 5 coal bed on Straight Creek.

	Inches.
Shale.	
Coal and shale.	
Shale	6
Coal	5
Shale	5
Coal	27
Shale.	

Peter and Talbutt[b] found the composition of this coal to be—

Analysis of coal No. 5 near Buena Vista furnace, on Straight Creek.

Moisture	3.20
Volatile matter	32.30
Fixed carbon	53.00
Ash	11.50
Sulphur	2.00

No openings on this coal were noted by the writer.

POTTSVILLE COALS.

A brief description of the rocks of the Pottsville formation has been given on pages 19–20, 62–64. It has been stated that the rocks of this formation are prevailingly sandy, and that associated with these sandy beds, which may be pure sandstone, sandy shale, or shaly sandstone, are three classes of economic deposits—coal, fire clay, and iron ore. In this place only the coals will be considered.

CATLETTS CREEK COAL (NO. 4).

Geologic position.—The highest coal in the Pottsville formation in this district may be called the Catletts Creek coal from the fact that it is exploited along the creek of that name. It corresponds stratigraphically with the Upper Stinson coal at Boghead and with the Lick Creek coal of the Big Sandy Valley district. Its position directly below the Homewood sandstone serves to locate it at once in the geologic column. Its distance above the next lower workable coal in this district is probably not more than 40 to 50 feet, and it lies approximately the same distance below the Vanport ("Hanging Rock") limestone in the Allegheny formation in the eastern part of Ashland, though this measurement depends largely on the varying thickness of the Homewood sandstone.

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[a] Kentucky Geol. Survey, vol. C, 1884, p. 19. [b] Idem, p. 20.

Extent and development.—Although this coal outcrops over a broad area in the district, it has proved of workable thickness in very few places. Its outcrop, if drawn on the map, would come a little below that of the clay indicated by the red line.

In the eastern part of Ashland it has been prospected at numerous points on the road leading to the city cemetery. Farther up Ohio River, at the Weaver Pottery Company's plant, between Sandy City and Catlettsburg, it was formerly worked, but the bank had fallen shut at the time of the writer's visit. It is probable that this coal may be of workable thickness between this point and Ashland, although there is a possibility that it may be replaced by the massive Homewood sandstone of this region. On Catletts Creek it is workable and may be easily traced for 2 miles west of Catlettsburg to a point where it disappears below drainage level. In the valley of Hood Creek, a short distance northwest of Summit, it has been opened by William Crane, and near the mouth of Shope Creek A. J. Harris, on whose land the coal has been opened, reports 3½ feet of coal with an important fire clay below. At Music it has been opened, but is so badly broken by partings as not to be a commercial coal. So far as known, it is not workable at any other point in the district. Developments on this coal are not on a commercial scale. In all the localities described above, except at the opening of the O'Kelly Brick Company, it is worked only during the winter months for local trade.

Character.—The reason for its restricted exploitation is at once evident from its section. It is, in fact, a thin coal bed, and this character, in connection with the fire-clay parting running through the center of the bed, will probably bar it from the list of commercial coals of this district for some time to come. Both benches nowhere measure more than 2½ feet together, and the parting in the middle is in places as thick as one of the benches of the coal. It usually has an excellent roof of massive sandstone, which makes it a safe and cheap coal to work. Its clay floor is important commercially, for it it is of workable thickness and of a quality good enough to serve as a bond in refractory brick. The coal could readily be worked at a profit in connection with the fire clay, and this seems to have been understood by one firm, the O'Kelly Fire Brick Company, which mines the clay and coal in the eastern part of Ashland (fig. 9, section 3). The coal is of the lustrous bituminous variety, but contains splinty bands and is on this account rather hard. It breaks into thin slabs and hence is blocky in its nature.

TORCHLIGHT COAL (NO. 3).

Geologic position.—The next lower workable coal in this district is at a distance of 40 or 50 feet below the base of the Homewood sandstone and hence at the same distance below the Catletts Creek coal.

East of Danleyton it has been opened, together with the coals occurring below it, at a few points about 80 feet below the top of the Homewood sandstone, which, in this region, is a prominent cliff maker and can be readily traced. This is not the second coal below the base of the Homewood sandstone, as on the Hood Creek pike two small beds were observed at small distances above this coal. It is very probable, however, that it is the next main workable coal below that occurring immediately beneath the Homewood sandstone. It is also certain that this coal, which is the one opened on the lands of the Means Russell Iron Company in the valley of Hood Creek, can not be the Catletts Creek coal, for the two coal beds are found in the section exposed from the point where the main Hood Creek pike crosses Hood Creek northwest of Pollard to the Flatwoods area. It is probable that it is the equivalent of the Torchlight coal of the Big Sandy River

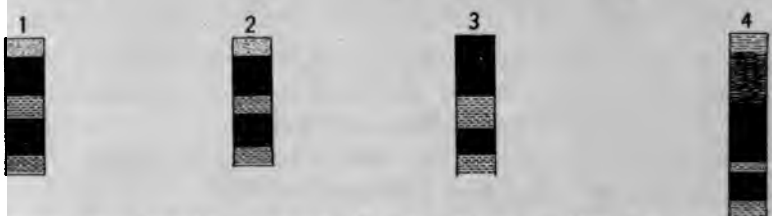


FIG. 9.—Sections of Catletts Creek (Kentucky No. 4) and Torchlight (Kentucky No. 3) coals in Boyd County. Catletts Creek coal: 1, Alex. Chapin, Catletts Creek; 2, country bank, Catletts Creek; 3, O'Kelly Brick Company, Ashland. Torchlight coal: 4, Hood Creek, west of Ashland. Scale, 1 inch = 5 feet.

region, and of the Lower Stinson coal at Boghead, and hence is No. 3 in the Kentucky series.

Extent and development.—This coal bed is present above drainage level in workable thickness over only a small part of Boyd County. Both to the east and to the south the dips carry it below drainage level. To the west and south, however, in Greenup and Carter counties, it is found above drainage level, having a wide distribution near the western limits of the quadrangle. Within this district it has been worked on only a small scale, owing to the fact that it is thin and badly broken by partings, but along Canes Creek and Stinson Creek in Greenup and Carter counties it is one of the most important cannel coals. It is present in workable thickness in the ridge separating Little Sandy River from East Fork, but on the eastern flank of the ridges it is not worked, except at a few country banks. Its outcrop, where known to be workable, is indicated on the economic map (Pl. I). The most important past development on this bed was in the valley of Hood Creek, west of the city of Ashland, directly overlying a massive sandstone. Though it has been opened in many places northwest of Pollard on the lands of the Means Russell Iron Company, all the openings have for some reason

been allowed to fall in. The section and character of the coal here are unknown. The following is a section of the bed:

Section of No. 3 coal bed of the Kentucky Geological Survey in the valley of Hood Creek, west of Ashland, Ky.

	Inches.
Shale roof.	
Coal with bony streaks	15½
Coal, bituminous, with splint bands	18
Clay	3½
Coal	9
Fire clay.	

The bank is situated so that it is often flooded at periods of high water. The above section is the only one in this district which the writer had an opportunity to measure; hence it would be unjust to base a judgment as to the character of the coal on such slight evidence. It is apparent at once that if the section is a true criterion of the bed, it has little market value at present. The upper bench, which is the main workable bench, may be all coal in many places and not largely bone as indicated. If this bony character is not widely prevalent the upper bench alone would have commercial possibilities. The parting between the two benches, in connection with the thinness of the lower bench, injures the value of this bed.

The coal in the upper bench is hard and contains splint bands, and like most of the coals in the region will bear stocking and transportation without much crumbling. On this account it is a coal which can be shipped for long distances and not suffer much in transit.

DANLEYTON COAL.

Geologic position.—The position of the Danleyton coal bed in the geologic column is very plainly indicated in the section between Argillite and Hood Creek (p. 64). It is known locally as the "clod seam," owing to a clay parting which it contains. Openings on it have been made at many places near Argillite and Danleyton, and it may be called the Danleyton coal. It occurs 110 feet below the base of the Homewood sandstone and from 30 to 40 feet below the horizon of an ore bed which must have been of considerable importance in the region, as it has been benched to a great extent. This ore has been regarded by Moore as the main block ore,[a] but its relations to the base of the Homewood indicate a lower ore. Certainly the coal opened below it is much too far below the Homewood to be regarded as the equivalent of the No. 3 or Torchlight coal.

Extent.—The Danleyton coal is present in the hills bordering East Fork of Little Sandy between Danleyton and Naples, but south of Naples it is below drainage level. Near Argillite it occurs 150

[a] Kentucky Geol. Survey, vol. C, 1884, p. 138.

feet above railroad grade, and has been opened in the surrounding hills. There is an almost continuous line of country banks on the outcrop where it is above drainage level on Culp and Henry branches, and nearly every farmer about Danleyton also has opened this coal for his private use. A short distance east of Danleyton it goes below drainage level. It has been opened near Hunnewell, on the Eastern Kentucky Railway, as described elsewhere (p. 92). At all these points the development is purely local.

Character.—The accompanying sections (fig. 10) illustrate the character of this coal. They show a striking similarity in their general features. The coal where seen is always in two benches, separated by a clay parting. Each bench ranges from less than a foot to 1½ feet in thickness. The lower 4 or 5 inches of the upper bench is in places bony. The clay parting ranges from 6 inches to more than a foot in thickness. In no place was more than 31 inches of good coal seen in both benches. The coal is of the usual bituminous variety. The upper bench is perhaps more lustrous than the lower, but

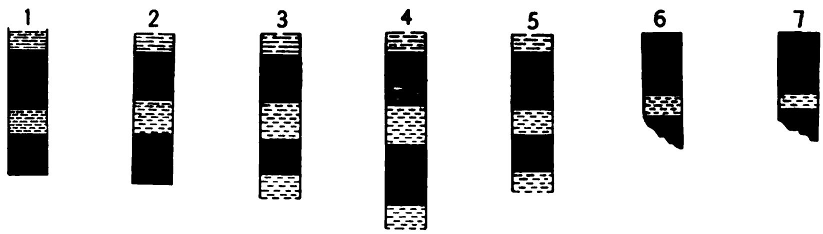


FIG. 10.—Sections of Danleyton coal. 1, Mouth of Pigott Branch; 2, J. H. Pruitt, Culp Creek; 3, mouth of Pigott Branch; 4, Henry Branch; 5, A. W. Callahan, Danleyton Church; 6, south of Danleyton; 7, Turkey Fork. Scale, 1 inch = 5 feet.

it may also be dull and splinty. The lower bench locally breaks out into blocks and contains splinty bands. The thinness of this bed and the presence of the clay parting are serious hindrances to its commercial possibilities. So long as thicker coals are prevalent in the region this bed can hardly compete with them in the trade. It is conveniently situated with respect to transportation, and in the future may be developed for shipment. It is reported to be an excellent stove and steam coal, and is widely used by the farmers.

LITTLE SANDY VALLEY OR EASTERN KENTUCKY RAILWAY DISTRICT.

EXTENT.

The Little Sandy Valley district is in the northwestern part of the Kenova quadrangle. Its eastern boundary is the ridge separating the drainage of East Fork of Little Sandy and Williams Creek from that flowing into Little Sandy River. It will be seen that this is an irregular line running southwest from the northern edge of the quadrangle to the ridge just west of Means tunnel. Southwest of

this point the boundary swings west and south to Mount Savage, thus allowing a part of the Little Sandy drainage basin to be included in the Chesapeake and Ohio Railway district. The line of the Chesapeake and Ohio Railway has been arbitrarily chosen as the southern limit of this area. The reason for the choice of these boundaries is that the district thus set apart is a unit commercially, all the coal mined in it being shipped over the Eastern Kentucky Railway, which follows Little Sandy River more or less closely till it reaches Ohio River.

GEOLOGY.

This district lies on the northwest side of the basin, which extends nearly across the quadrangle from its northeastern to its southwestern border. The beds dip southeast. It will be seen at once that from the center of the basin to the northwestern edge of this area lower and lower beds appear in the valleys. Therefore the lowest beds stratigraphically are those in the valley of Tygarts Creek.

The rocks outcropping in this district occur in both the Pennsylvanian and the Mississippian series. The former series in this district includes the Pottsville formation and a part of the Allegheny. The Mississippian series includes the Maxville limestone lying at its top and a part of the Waverly group.

The Allegheny formation is, for the most part, confined to the hills east of Little Sandy River, but its base is present in the tops of some of the highest hills between Little Sandy River and Tygarts Creek.

The next lower formation is the Pottsville. Considered from both an areal and an economic standpoint this is the most important formation of the region. Its entire thickness is represented and, since it differs so markedly from its equivalent in the Big Sandy River region, it has been thought advisable to prepare a general columnar section which will represent it in this district (Pl. IV, p. 28). It includes the rocks from the top of the Maxville limestone to the top of the Homewood sandstone, in all very nearly 400 feet. In some places it may be thicker than this, but in others its thickness may be nearer 300 feet. The prevailing character of the rocks in this formation is sandy. Lying 20 to 30 feet above the Maxville limestone occurs the lower and one of the most important sandstone members in the Pottsville—the " conglomerate rock " or " conglomerate formation " of the Kentucky Geological Survey. It is not a simple sandstone at all points; on Everman Creek a distinct black shale which locally contains coal occurs near its middle. The fossils obtained from this shale point to its equivalence with the Jackson shaft coal of Ohio and the Sharon coal of Pennsylvania. At the top of the Pottsville is another important sandstone member, the Homewood sandstone, ranging from 25 to 50 feet in thickness in this particular district, though in other parts of the area it may attain a thickness

of 100 feet or dwindle to a few feet of sandy shale. There are other important sandstones in this area; for example, below the Danleyton coal about Argillite and Hunnewell a massive sandstone 60 to 70 feet thick shows in the hills, and locally the shaly sandstones and sandy shales so characteristic of this formation assume a decidedly sandy phase, becoming, in fact, true sandstones. The deposits of chief economic interest in the Pottsville are coal, clay, and iron ore. There are at least four different coal horizons, attaining importance in different parts of the district, and if the thin beds which are used locally but which may never assume much commercial importance be counted the number is considerably increased.

The next lower member in the section is the Maxville limestone. This rock has some economic importance but does not contain any coal beds. It is very restricted in its distribution; it outcrops on Everman Creek at a few points and in the valley of Tygarts Creek. It is not over 20 or 25 feet thick.

The Waverly group underlies the Maxville limestone. Its best development in this area is in the valley of Tygarts Creek. In the hills about Warnock G. H. Ashley measured a little over 100 feet of this group, composed of shale, shaly sandstone, and sandstone. The Waverly group has been divided into several formations, the topmost of which are the Logan, 100 to 150 feet thick, and the Blackhand, 50 to 500 feet thick. There are no grounds to warrant dividing the rocks below the Maxville into more than one formation in this area. They may be regarded, therefore, as belonging to the Waverly group. They are of minor economic importance, as they contain no coal beds, clay, or iron ore within the limits of this district.

THE COALS.

ALLEGHENY COALS.

The rocks included in the Allegheny formation in this district lie chiefly east of Little Sandy River and cover only a small part of the surface. The two important coal beds in the lower half of the Allegheny—namely, the Coalton and the Winslow—are present in small areas on the divide between Little Sandy River on the west and East Fork and Williams Creek on the east. These deposits in general are rather small to be exploited commercially, though in some localities considerable coal has existed. At the head of Stinson Creek, for instance, the Coalton coal is of some importance. The remaining coal beds of the Allegheny formation, outcropping along the eastern margin of the Little Sandy River region, owing to its southeastern dip, will be worked and shipped along the Chesapeake and Ohio Railway and are considered in the description of the district tributary to that line (pp. 60–82).

POTTSVILLE COALS.

UPPER STINSON COAL (NO. 4).

Geologic position.—The highest workable coal in the Pottsville formation occurs near the base of the Homewood sandstone. It thus corresponds in position with the Lick Creek coal, south of Louisa, and the Catletts Creek coal. It is opened and worked at Boghead by the Kentucky Cannel Company, where it occurs 30 feet above the Lower Stinson coal. Strictly, then, this coal should be called coal No. 4, if we are to adhere strictly to a system of numerals for the coal beds. Both this coal and the underlying bed fall within the Mercer group of northwestern Pennsylvania.

Extent and development.—This coal has been called the "Yankee vein" near Hunnewell, and according to report has been worked near that place. It is of workable thickness over a fairly broad area. It is present and as a rule is of workable thickness in most of the hills of this district east of Little Sandy River. Workable thickness is

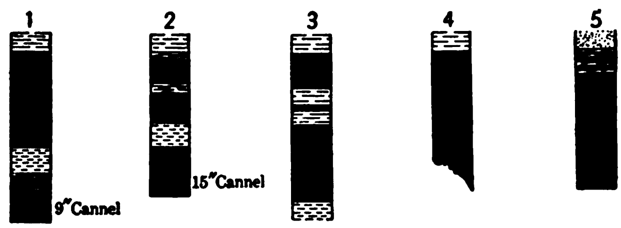


FIG. 11.—Sections of Upper Stinson coal (Kentucky No. 4). 1, 2, Kentucky Cannel Company, Boghead, Ky.; 3, Miss Drendy Jacobs, hill west of Canes Creek; 4, 5. Mount Savage. Scale, 1 inch=5 feet.

reported about Hunnewell, but its greatest thickness is to the southwest, in the hills at the head of Wilson and Upper Stinson creeks. In places it is a splint and bituminous coal, and at Boghead it contains an important cannel layer.

At the head of the smaller tributaries flowing into Wilson Creek from the east it is opened on the places of Miss Drendy Jacobs and C. G. Brammell. At an opening on Miss Jacobs's property the thickness of this bed is well shown (fig. 11, section 3). On the county road between Boghead and Seney its bloom shows, but the coal has not been opened and little is known of its thickness and character. On Lower Stinson Creek it is worked by the Kentucky Cannel Company at Boghead, and according to report the old Lexington and Carter Coal Mining Company worked the bed in the past in the hills southeast of the present openings of the Kentucky Cannel Company, shipping their coal overland to the Chesapeake and Ohio Railway at Music Still farther south, in the hills north of Mount Savage furnace, this coal has been opened and worked, though it is rather thin and badly

broken by clay partings. At some of the prospects visited at other points near Mount Savage it shows an excellent section, as seen in fig. 11 (sections 4 and 5). This coal, therefore, is present in workable thickness over considerable territory lying between the heads of Canes Creek and Straight Creek. West of Little Sandy River it is present only near the tops of the highest hills.

Character.—It will be seen from a study of the sections of this coal bed that it is very irregular in thickness. The coal at Boghead is comparable with that measured west of Canes Creek at the bank of Miss Drendy Jacobs. At both these points the bed consists of three benches, separated by either bone or black clay or shale partings. The coal in the upper bench ranges from 7½ to 11½ inches, and in places has a few inches of bone over it. The middle bench ranges from 1½ to 11 inches and is of soft bituminous coal, as is the upper bench. These two benches are separated by a parting not exceeding 6 inches thick of bone or black shale. At Boghead the coal shows a bottom bench of cannel, varying between 9 and 15 inches, and separated from the middle bench by about 6 inches of bone or clay. In most places the coal bed has a clay floor and a shale roof which requires careful timbering. West of Cane Creek the coal in the upper two benches is soft lustrous bituminous coal, as at Boghead, but the bottom bench, which measures 2 feet or more, is splinty and dull. At Mount Savage the coal appears to be irregular, showing in one place the simple section indicated in sections 4 and 5 (fig. 11), but in other places being badly broken by clay or shale partings and having a roof of shale or clay or the massive Homewood sandstone. This coal is opened at many country banks near Mount Savage.

West of Canes Creek near the Greenup-Carter county line this coal is developed in three benches; the upper two are ordinary soft lustrous bituminous coal and the lower bench is hard and splinty. Both varieties are mined for local use in the region and give excellent results when used for domestic and steam purposes. At Boghead also the upper two benches are soft ordinary lustrous bituminous coal mined in connection with the cannel but kept separated from it. The cannel from the lower bench is peculiar in structure. It is not homogeneous and compact and does not break with the conchoidal fracture characteristic of the more familiar types of cannel coal when seen in large lumps. It is irregularly bedded, or lenticular, the individual beds or lenses varying greatly in their two larger dimensions. In places the width, however, is not more than an inch. The thickness of these lenses varies; in some places they are from a quarter to a half inch thick, but elsewhere they are exceedingly thin. Along the bedding planes are flecks of lustrous material. These may be due

1) to material of different composition originally or (2) to material which may possibly have undergone less physical change (maceration) before consolidation, or (3) some of these patches may be lickensided surfaces or planes of movement, suggesting the possiility that the structure of the rock may be secondary and due to novement after the coal had been deposited. When examined closely he material composing the lenses is seen to be typical cannel in every ray, having the dull appearance of more massive cannel coal, breakig with conchoidal fracture, and being homogeneous and compact, all n a small scale. With the exception of the small lustrous patches nd its structure when viewed in large-sized fragments, it is like nore massive cannel coal. The coal mined from this bench is kept eparate from the bituminous coal of the same bed and, with the annel from the next lower bed, is shipped abroad, where it is used hiefly as a gas enricher, being very high in volatile matter and fairly ow in fixed carbon and moisture.

LOWER STINSON COAL (KENTUCKY NO. 3).

Extent.—The next lower workable coal in the Pottsville formation ccurs 30 feet below that just described. Thus, were the numbers aplied to coals which are workable locally, this would really be No. 3 in e series. This is probably equivalent to the Hunnewell cannel coal. n the past it was extensively worked in the vicinity of Hunnewell urnace and the cannel in it was said to range in thickness from 3 to feet. It is present in all the hills in this district east of Little andy River, becoming higher in the hills toward the west. North f Turkey Fork it seems to lose its cannel bench, but south of this ream it is worked by the Kentucky Cannel Company near Hunneell for the cannel it contains. At the head of Canes Creek its bloom nows at several points along the road, but little prospecting has been one on it and not much is known of its character. Its most imortant area in this district, and, indeed, in the entire western part f the whole quadrangle, is the irregular square included between ower Stinson Creek on the north, the limits of this district on the ast, the Chesapeake and Ohio Railway on the south, and Little andy River on the west. In this area it is fairly uniform in thickess, though it varies somewhat in physical character. At Boghead is worked by the Kentucky Cannel Company on a commercial cale, chiefly for its cannel bench, which occurs near the middle of e bed. On the waters of Upper Stinson Creek it has been opened numerous points. West of this creek and between it and Little andy River the coal bed seems to lose its cannel bench at most oints and to consist of two benches of ordinary bituminous and plint coal. In the hills about Robin Run and the small tributaries

of Little Sandy River southeast of Grayson it has been opened at many points and in every place is of fair workable thickness. The persons on whose land the coal is worked and where measurements were obtained are named on page 89. Most of the hills west of Little Sandy River rise high enough to contain this coal bed, but at the time of the writer's visit apparently very little prospecting had been done on the bed in this region and its identity with the coal described southeast of Grayson could not be established with any great degree of certainty. What is considered the equivalent of the Lower Stinson coal has been opened on Barrett Creek and Everman Creek and contains some cannel coal in both benches, as indicated in the section obtained on the land of David Childers (fig. 12, section 12). North of Everman this coal is present over broad areas in the hills bordering Claylick, Oldtown, Lost, and Canes creeks and Fall Branch, but at no points were any openings in such condition as to enable the writer to measure or study the coal in detail. Near the mouths of these creeks the coal will be found between 200 and 300 feet above the bottom lands. Crandall[a] states that in the neighborhood of Raccoon, Buffalo, and Laurel furnaces, which are located in or near the northwest corner of this district on Raccoon, Claylick, and Oldtown creeks, respectively, this coal is present and usually 3 feet thick. There seems to be no reason why it should not be present in workable thickness over a considerable area west of Little Sandy River.

Character.—The sections in fig. 12 give an idea of the thickness of this coal and the number and character of its partings.

As will be seen from the sections the coal in some places consists of two and in other places of three or even four benches. Southeast of Grayson, at most of the country banks, it contains two benches (sections 2, 3, and 4, fig. 12), separated usually by a thin bone parting. The upper bench ranges from about a foot to 15 inches in thickness; the lower averages about the same. The coal varies in character in the two benches. At some points a cannel layer, from 1 to 2 inches thick, is present at the top of the upper bench, and at the George Armstrong bank (section 2, fig. 12) a 6-inch cannel layer was observed at the top of the lower bench. As a rule, the lower bench is more splinty and harder than the upper, but this is not invariably true. This bed averages about 2½ feet of excellent coal in the region southeast of Grayson. On Everman Creek (section 12, fig. 12) it contains more coal but also has a bad bony parting.

Where worked at Boghead and Hunnewell, the bed usually consists of three benches. The upper bench is ordinary lustrous bituminous coal and varies in thickness, being about 5 inches thick at Boghead and slightly less than a foot at Hunnewell. It is separated

[a] Kentucky Geol. Survey, vol. C, 1884, pp. 17–18.

from the middle cannel bench by a bone or clay parting, which is from 1½ to 9 inches thick, being thicker near Hunnewell than at Boghead. The bottom bench is similar in character to the top bench. At Boghead it ranges from a foot to 14 inches in thickness, and at Hunnewell it is slightly thinner. It is separated from the middle cannel bench by a clay parting of variable thickness, this parting at Boghead reaching about 20 inches. The middle bench of cannel coal is the most valuable part of the bed at Boghead and Hunnewell. At the latter place it is about 15 inches thick. At the old Hunnewell workings 3 to 4 feet of cannel coal were reported as formerly mined, but no such thicknesses as this are now being worked. At Boghead

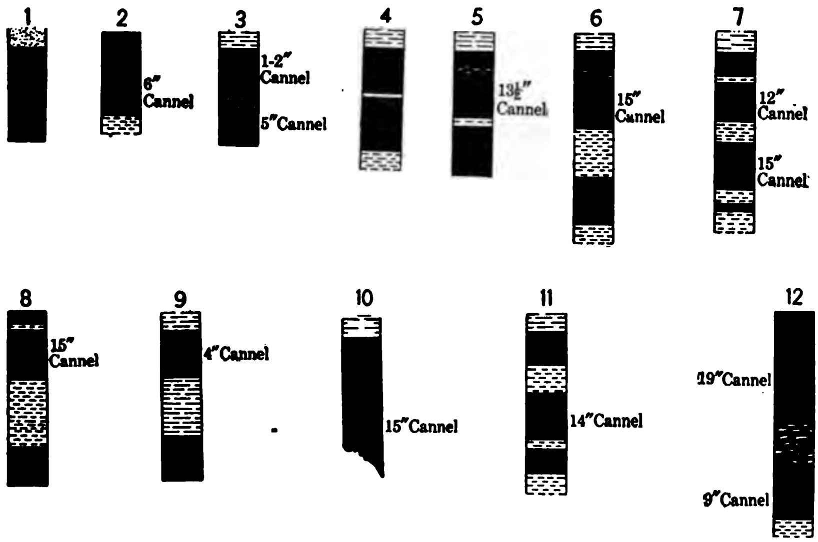


FIG. 12.—Sections of Lower Stinson coal (Kentucky No. 3). 1, Hill east of Grayson; 2, George Armstrong, 2 miles southeast of Grayson; 3, Robin Run, 2 miles southeast of Grayson; 4, John Crawford, Robin Run; 5, 6 (measured by G. H. Ashley); 7–9, Kentucky Cannel Coal Company, Boghead, Ky.; 10, 11, Kentucky Cannel Coal Company, Hunnewell mine; 12, David Childers, Everman Creek. Scale, 1 inch = 5 feet.

it is of about the same thickness, but at one point Doctor Ashley measured 27 inches of cannel, separated near the middle by a brown slate or clay parting 5 inches thick. George R. Hislop, of the Paisley Gas Works, Paisley, Scotland, has examined the cannel coal from the Boghead and Hunnewell districts. Of the former he says: "A sample of this coal representing the entire product of the seam is black and possesses a yellowish-brown streak and high luster. The fracture is slaty, coarse, and dull, with impressions of stigmaria, while in cross fracture it is conchoidal, with coatings of fire clay on the natural partings [joint planes presumably]. It is very compact and cohesive. On the fire it partially and slightly intumesces. The color of the ash is brown. It is well defined in stratification and is

of very uniform density." His report on the Hunnewell cannel coal is as follows: "The coal is black, possesses considerable luster and yellowish-brown streak. The fracture is slaty, coarse, and partly semiscalariform, with numerous impressions of stigmaria. The cross fracture inclines to conchoidal, with deposits of calcium carbonate, clay, and iron bisulphide [pyrite] on the natural partings [joint planes]. It is massive, compact, and very cohesive. On the fire it does not intumesce. The color of the ash is pale brown. It is well defined in stratification and of very uniform composition and density."

Both the Boghead and Hunnewell cannels were analyzed and subjected to practical tests by Mr. Hislop, with the following results:[a]

Results of tests of Kentucky cannel coal.

	Boghead.	Hunnewell.
Specific gravity	1.175	1.215
CHEMICAL ANALYSES.		
Moisture expelled at 212° F. ... per cent	1.21	2.75
Volatile matter ... do	54.92	47.23
Fixed carbon ... do	35.17	43.58
Ash ... do	8.08	5.55
Sulphur ... do	.62	.89
GASEOUS PRODUCTS.		
Gas per ton of coal at 60° F. and 30 inches barometer ... cubic feet	14,752	14,260
Gas from 1 cubic foot of coal ... do	541.37	483.44
Specific gravity of the gas ... air 1,000	700	644
Hydrocarbons absorbed by bromine ... per cent	15.33	14.25
Durability of 1 cubic foot by 5-inch jet flame ... minutes	$72\frac{1}{8}$	$66\frac{13}{15}$
Value of 1 cubic foot of gas in sperm ... grains	915.60	843.12
Value of gas from 1 ton of coal in sperm ... pounds	2,158.72	1,725.86
Illuminating power of gas in standard candles ... candles	38.15	35.13
Sulphureted hydrogen (H_2S) in foul gas ... per cent	1.25	1.75
Carbon dioxide (CO_2) in foul gas ... do	2.50	2.50
Carbon monoxide (CO) in foul gas ... do	7.00	5.50
Sulphur eliminated with volatile products ... pounds	9.85	12.09
LIQUID PRODUCTS.		
Tar per ton of coal ... gallons	20.34	20.12
Ammoniacal liquor per ton of coal ... do	4.43	11.31
Strength of ammoniacal liquor ... ° Twad	4.00	3.00
Hygrometric water per ton of coal ... gallons	2.71	6.16
Aqueous absorbent capacity of coal (determined by complete saturation) ... per cent	1.35	2.80
SOLID PRODUCTS.		
Coke per ton of coal ... pounds	972.83	1,108.35
Carbon in the coke ... per cent	81.40	88.80
Ash in the coke ... do	18.60	11.20
Sulphur in coke per ton of coal ... pounds	4.03	7.84
Heating power of 1 pound of coke (water from boiling point into steam), pounds	11.18	12.20

In summarizing the properties of these cannels Mr. Hislop makes the following statements. Of the Boghead cannel he says:

This is an exceedingly rich cannel coal, yielding, as it does, an illuminating equivalent of 2,158.72 pounds of sperm candles per ton, while the coal contains a very small percentage of water and a moderate amount of sulphur. This

[a] Mr. Hislop's results were kindly furnished by Mr. S. G. Bates, of the Eastern Kentucky Railway.

coal will be found a valuable one for the enrichment of inferior gases. Compared with main Lesmahagow cannel coal, represented by 100 (calculated on the basis of a production of 13,000 cubic feet of gas and 1,535.5 pounds of sperm per ton, and having regard also to the value of secondary products and the cost of purification of the gas), this coal is equal to 134.03.

Of the Hunnewell cannel coal he says:

This is a remarkably rich cannel coal; it is easily distilled, yields a large volume of 35.15 candle gas, and affords 9.9 hundredweight of coke per ton of medium quality, and quite available for heatings in furnaces or producers in combination with that from a bituminous coal. The coal contains about the average amount of sulphur, but a very small per cent of water. Compared with main Lesmahagow cannel coal, represented by 100 (calculated on the basis of production of 13,000 cubic feet of gas and 1,535.5 pounds of sperm per ton, and having regard also to the value of secondary products and the cost of purification of the gas), the coal is equal to 111.23.

In the Kentucky State mine inspector's report for 1899[a] there are some interesting comparisons given between other cannel coals of Kentucky and certain type cannels of Great Britain. The Boghead and Hunnewell cannel coal compares favorably with these, as will be seen from the following table:

Results of tests on cannel coals of Great Britain and Kentucky.

Location.	Gas per ton of coal (cubic feet).	Illuminating power of gas (standard candles).	Value of gas from 1 ton of coal (pounds of sperm).	Coke per ton of coal (pounds).
GREAT BRITAIN.				
Lesmahagow	13,201	34.52	1,562.00	1,019
Tyne Boghead	13,155	38.22	1,723.00	1,301
New Battle	12,461	35.34	1,509.00	983
KENTUCKY.				
Falling Rock	14,210	36.15	1,761.51	1,178
Bear Creek	14,630	41.24	2,069.00	995
Pineville Coal Co.:				
Boghead, Bell County	15,805	36.26	1,964.87	1,089
Willaford	15,835	41.55	2,418.68	995
Kentucky Cannel Co.:				
Boghead, Carter County	14,752	38.15	2,158.72	972.83
Hunnewell, Greenup County	14,260	35.13	1,725.86	1,108.35

With main Lesmahagow cannel coal as 100 (calculated on a basis of a production of 13,000 cubic feet of gas and 1,535.5 pounds of sperm per ton, and having regard also to the secondary products and the cost of the purification of the gas)—

Falling Rock cannel is equal to	112.07
Bear Creek cannel is equal to	137.11
Pineville Willaford cannel is equal to	148.81
Kentucky Cannel Company's Boghead cannel is equal to	134.03
Kentucky Cannel Company's Hunnewell cannel is equal to	111.23

The figures and analyses given above need hardly any comment. They indicate that the cannel coals of this district now worked by the

[a] See pp. 111–115 of that report.

Kentucky Cannel Company are of the highest grade, the only hindrance in mining being the moderate extent of the territory underlain by them, in which respect they are like most other cannel coals.

DANLEYTON COAL.

Extent.—About 60 to 70 feet below the Hunnewell cannel coal is a bed which has been dug near Hunnewell and which outcrops on the hill on Cane Creek to the south. It also occurs in the hill 2 miles southeast of Grayson in a similar position, but locally at a greater interval below the Lower Stinson coal. About Hunnewell it is called the "clod seam," but it can not be positively stated that this is the "clod seam" of the Danleyton-Argillite district. The presumption is strongly in favor of their identity, but at the time of visit the opening at Hunnewell had fallen shut and the coal could not be seen. It is probable that the bed occurring near Hunnewell about 110 feet above the road is the Danleyton bed, as the two are characterized by an unusually massive underlying sandstone, and their distance, 100 feet below the base of the Homewood, is about the same. Near Hunnewell depot, about 30 feet below this bed, is a 10-inch coal which is probably not workable in this district, and on Turkey Fork a small 4- to 5-inch bloom was seen about the same distance above it. It is possible that these coals are those reported by Moore as occurring above Crandall's No. 1 coal[a] near Raccoon, Buffalo, and Laurel furnaces; hence the coal under discussion would properly be called No. 2 in the series of workable coals in this region. The difficulties in the way of correlating this coal bed with a coal bed west of Little Sandy River are many. East of Little Sandy River, on Culp Creek, Turkey Fork, and Cane Creek, the position and relationship of this coal are fairly clear with reference to the key rocks at the top of the Pottsville and at the base of the Allegheny. West of Little Sandy River the latter beds are generally absent from the hills, hence there is nothing definite to tie to except the Sharon conglomerate, which is somewhat scanty in its areal distribution.[b] It is believed, however, that this bed is not of any great importance west of Little Sandy River, a conclusion similar to that reached by Crandall.

Development.—East of Little Sandy River it has been opened on many farms near Argillite, but never has been shipped, so far as known. A description of the coal in this immediate region has been given on page 82. Farther south, in the hills along the Eastern Kentucky Railway, it is present, and has been opened on Turkey Fork and near Hunnewell,[c] 110 feet above the county road. The bloom of this coal shows on Black Branch of Little Sandy, east of Pactolus,

[a] Kentucky Geol. Survey, vol. C, 1884, p. 16. [b] Idem, p. 46. [c] See p. 82.

and in general on all the county roads east and southeast of Grayson ascending the small creeks to their sources. On Upper Stinson Creek, near Stinson, a coal, presumably the Danleyton, lies 100 feet below the old workings of the Lexington Carter Company, which has been reported as working the Upper Stinson or No. 4 coal. This would make the coal come about 70 feet below the Lower Stinson cannel coal. It has been prospected at this point, and was reported 22 inches thick with two partings. A small coal 20 to 30 feet above it occurs here similar to that on Turkey Fork.

West of Little Sandy River the first coal bed of any importance above Crandall's No. 1 on Barrett Creek, being thus No. 2 of the Kentucky series, is found about 120 feet above the top of the Sharon conglomerate. It is approximately 60 feet, or slightly more, above Crandall's No. 1 of this region, and about the same interval, or slightly more (70 feet), below No. 3 coal. West of Little Sandy River this coal is usually present, but, like the first workable coal bed

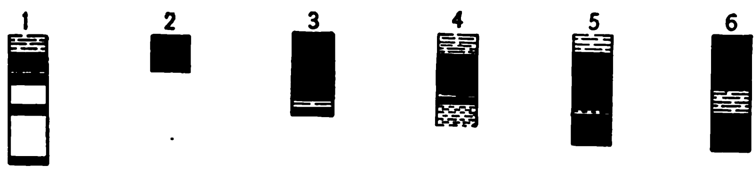


FIG. 13.—Sections of Danleyton and Barrett Creek coals. Danleyton coal: 1, 2, Everman Creek. Barrett Creek coal: 3, George Everman; 4, John Duley, Wolfpen Branch of Everman Creek; 5, A. J. Womack, Right-hand Fork of Everman Creek; 6, Near Samaria, Lost Creek. Scale, 1 inch = 5 feet.

above, it is opened at so few points that a good idea of its characteristics can with difficulty be obtained. Two openings on Everman Creek were visited, but the coal is so badly broken by bone partings as hardly to be valuable. Sections 1 and 2, fig. 13, show the coal as measured. It should be added that these sections were measured near the outcrop, where the true character of a coal is sometimes obscured. At the bank of David Childers, where the second section was obtained, it was reported that there are 3 feet of coal. At the time of the writer's visit in October the owner had not begun to dig his winter supply of fuel and the inner workings were not accessible. It is questionable whether this bed will add much to the coal resources of this district.

BARRETT CREEK COAL (NO. 1).

Extent and development.—The next lower workable coal corresponds to No. 1 of the Kentucky Geological Survey. In Crandall's general section this coal is placed about 40 feet above the top of the Sharon conglomerate, which is practically the same position as is

given to it in the writer's general section. (See Pl. IV, p. 28.) It is about 60 feet below the next higher workable coal, but its position with reference to the Sharon conglomerate where this bed is present will serve in most places to identify it. Crandall has stated that "it appears to be the equivalent of the Jackson Shaft coal in Ohio."[a] This is perhaps placing the equivalent of that Ohio coal a little too high in the Kentucky series, for the coal associated with the black shale lying within the Sharon conglomerate on Everman Creek appears to contain a fossil flora similar to that of the Jackson Shaft coal of Ohio, and hence is probably more nearly the stratigraphic equivalent of the Ohio coal than the bed 50 to 60 feet above the top of the Sharon.

The coal has been developed on Barrett Creek at many points. It has also been opened on Wolfpen Branch and Righthand Fork of Everman Creek. On Canes Creek, about 2½ miles west of Hopewell station, it has been opened by Marion Smith, and though reported thin it is of excellent quality for smithing purposes. On Lost Creek near Samaria it has been opened on the land of Mr. Stevens. Its bloom also shows on Oldtown Creek and its north fork. It is present in all the hills in this district west of Little Sandy River and will be found in workable thickness, at least for local use, over a broad area.

East of Little Sandy the coal is not so extensively distributed above drainage level owing to the eastern dips. Between Argillite and Laurel it appears as a small bloom at a few points on the county road along the Eastern Kentucky Railway, but has not been opened, so far as known. It is probably this coal which is opened at a few points on Cane Creek south of Hunnewell, where it is about a foot thick.

Character.—The sections in fig. 13 give an idea of the thickness of the Barrett Creek coal. The sections show that it is comparatively thin, and, though usually of workable thickness, at many points it falls below what might be regarded as commercial requirements for this region, namely, 2 feet. It consists at most points of two benches, an upper carrying from 1 to 2 feet of coal, and a lower, usually thinner, ranging from 2 inches to a foot. It has near its base a clay, shale, or bone parting, in places 6 inches thick. Crandall[b] reports this coal bed as being at Raccoon furnace, just north of the northwestern corner of this area, about 30 inches thick; near Buffalo furnace on Claylick Creek 3 feet, with a clay parting near its middle; and near Hopewell station 3 feet. The coal is, for the most part, of the soft bituminous type, but in some places the lower bench is hard and splinty. Mr. Ashley observed a thin cannel bench at the top of the upper bench on Lost Creek. The coal is regarded as of very high grade for local and smithing purposes.

[a] Kentucky Geol. Survey, vol. C, 1884, p. 11. [b] Idem, pp. 11–13.

LOWER COALS.

About 50 to 60 feet below the Barrett Creek coal occurs a single small coal bed and in places a second coal a few feet still lower. These are thin beds lying near the top of the Sharon conglomerate, and possibly the lower coal is within the stratigraphic equivalent of the Sharon. Where only one of these coals is present it is impossible to tell which of the two it is. One of these coals was exposed in an excavation below the post-office at Grayson and appears at several points on the county road south of the town. It was opened in the bed of Town Branch to the west. It rests directly on a thin bed of quartz or quartz-like micaceous sandstone, not over 5 to 6 feet thick, which is a fairly persistent stratum in the immediate neighborhood of Grayson. The two coals near the bridge over Little Sandy River, east of Grayson, are probably equivalent to the coals just mentioned south of the town. They also are too thin to work at this point. In the valley of Upper Stinson Creek directly east of Grayson two coals show just at the foot of the hill to the left of the road going east, and at the edge of the meadow the lower of these coals is 20 inches thick and has a bone floor and a shale roof. The fossils collected by Mr. White were not distinctive. Near the north end of the tunnel of the Eastern Kentucky Railway, south of Hopewell, this coal shows, but here also is too thin to work. The coal was also noted east of Pactolus on the hills near Black Branch, where it is too thin to export, though it is of some local importance.

The lowest coal of importance in this region occurs within the Sharon conglomerate itself. The dual character of this sandstone member is shown on Everman Creek near its junction with Wolfpen Branch, where a black shale is present 15 to 20 feet below its top. In places this shale is coal bearing, and the thin coal found in this position at the farm of John Duley farther up Wolfpen Branch is regarded by David White as the stratigraphic equivalent of the Jackson Shaft coal of Ohio and the Sharon of Pennsylvania. This coal has also been worked on Barrett Creek almost at water level. Opposite the residence of L. D. O'Roarke 6 inches of coal shows. The coal has been opened farther up the creek, where the county pike turns over the hill to Everman Creek. On Canes Creek the Sharon is very massive, and this coal again appears but is only 6 inches thick. Like the other coals below No. 1, this is too thin to be commercially valuable.

DISTRICT TRIBUTARY TO SOUTHERN TERMINUS OF EASTERN KENTUCKY RAILWAY.

EXTENT.

The district, including approximately the southwestern quarter of the quadrangle, contains in its northern part the southern 8 miles of the Eastern Kentucky Railway, passing through Willard and ending

at Webbville. Nearly all the lumber, staves, and country merchandise shipped out of this region go via this railroad, hence the reason for applying the above title to it. It includes all of Elliott County within the Kenova quadrangle, the extreme western part of Lawrence County, and a very small portion of southern Carter County.

GEOLOGY.

STRATIGRAPHY.

The Conemaugh, Allegheny, and Pottsville formations are represented in this district. In the northern part, east of Willard, in the deepest part of the basin, the surface is entirely made up of Conemaugh rocks. Immediately west of Willard and in a few isolated areas on the hilltops west of Dry Fork, Conemaugh rocks outcrop. A good idea of the character of this group of rocks may be had by climbing the hill east of the mouth of Thompson Fork or ascending Lost Branch, Belle Trace Creek, Beetree Fork, or Straight Creek east of Denton. Between 300 and 400 feet of the Conemaugh is shown, consisting of sandstones, shales, limestones, iron ore, and coal streaks. The coal in this formation is too thin and pockety to be of any importance except locally. There are at least three or four thin beds of limestone, the most persistent being a siliceous bed 4 to 5 feet thick lying near the base of the Conemaugh, about 180 feet above the Coalton coal as measured at Willard. This limestone and possibly the higher beds might be used locally as a source of fertilizer. The lower limestone probably corresponds to one of the Cambridge limestones of the Ohio geologic section. There are some rather massive sandstones scattered through the group of rocks, notably in its lower 100 feet. Some of the sandstone appears to be good enough for building purposes.

The Allegheny formation is in this district, as usual, the most important from an economic standpoint. A section measured west of Willard gives a fair idea of the sequence of the coal beds in it. It must not be understood that all the coals observed in this section will appear in the Allegheny, in other parts of this district, for the formation is somewhat variable. As an instance of this, on the west side of the hill where the following section was measured the formation had thinned somewhat, and, though the exposures were fairly good, fewer coals were found in it.

Section in hill west of Willard, Carter County.[a]

Top of hill.	Feet.
Sandstone, massive, and sandstone débris	45
Limestone, massive, drab, fossiliferous (Cambridge limestone)	4–5
Partly concealed with sandy débris and sandy shales	60

[a] This section represents the average of two distinct barometric determinations.

	Feet.
Sandstone, massive, white to light brown	25
Coal bloom No. 9 (top of Allegheny).	
Fire clay	2–3
Shale, sandy, and shaly sandstone	20
Coal bloom No. 8.	
Concealed and sandy	15
Limestone, yellow	1½+
Shale, drab	15
Coal (workable) No. 7.	
Sandstone, laminated	20
Ore, limestone.	
Concealed	10
Coal bloom No. 6.	
Shale (fire clay at top)	15
Coal, two small blooms 6 inches apart.	
Shale and fire clay	20
Coal bloom No. 5.	
Sandstone, laminated	10
Sandstone, massive (Homewood)	30
Coal bloom (coal has been worked).	
Fire clay.	
Sandstone and shale	15
Coal bloom (coal has been worked).	
Sandstone	10±
Base of hill.	

The Allegheny formation ranges in this district from about 120 et to possibly 200 feet in thickness. In places it may even be thin- r than 120 feet. It includes at least three valuable coal beds work- le at different points, at least one valuable fire clay, and iron-ore posits, but the bulk of it, as usual, is composed of sandstone and ale. It forms the surface in a more or less irregularly curved strip, hich follows the direction of the contour lines from Straight Creek the southwest and then trends southeastward to the limits of this strict. Many of the hilltops west and south of the main Allegheny lt are formed by this group of rocks. Roughly, it covers about one- ird of the surface in this district.

The lowest formation present in this district is the Pottsville. In aces it is between 500 and 600 feet thick, and it is prevailingly ndy throughout, though containing some shale beds. Its two most ominent members are the Homewood sandstone near the top and e Sharon conglomerate near the base, each of which attains in many aces a thickness of 100 feet of very massive rock. The Homewood ember is broadly distributed; the line of outcrop of its top, if repre- nted on the map, would coincide very closely with the red line which dicates the outcrop of the fire clay associated with the Vanport Hanging Rock") limestone. The Sharon conglomerate appears the valley of Little Sandy River, along Brushy, Hood, and Upper

and Lower Laurel creeks, and on Field Branch. Roughly, this formation covers perhaps about one-half of the surface in this district. The Pottsville formation is of importance economically, containing coal beds locally workable and at some points cannel coals. It also contains iron ore, fire clay, and sandstone of value. These beds are described in detail under the appropriate headings.

STRUCTURE.

The structure of this district is more involved than that of any of the districts previously described. The synclinal trough which traverses the quadrangle from northeast to southwest begins to die out in the vicinity of Willard and Webbville. Between these two towns the basin rises sharply toward the west. About Webbville and to the south the beds are generally inclined to the north and northeast; about Willard and to the north the pitch to the southeast is very sharp. Near Daniels Creek the Homewood sandstone thickens abruptly toward the west, giving rise to a slight dome in the rocks lying on the top of this sandstone and to a slight depression or basin as it becomes thinner again toward Cherokee Creek. West of Cherokee Creek the structure is not marked, though there is a gradual westward rise of the beds. About the town of Blaine the beds dip more sharply than at any point in the area, and at the bridge over Hood Creek apparent dips range from 11° to 24° in a nearly due north direction. Mr. Ashley discovered two minor faults in the hills east of Blaine, but they are of small magnitude, and a short distance away the beds can be traced continuously.

THE COALS.

CONEMAUGH COALS.

The blooms of a few coal beds show wherever any considerable section of the Conemaugh formation is exposed. A small coal bed occurring within 10 feet of the bottom of the Cambridge limestone appears to be fairly persistent and has been dug for local use near the head of Belle Trace Creek, Jordan Fork, and Straight Creek. This coal is not commercially valuable.

ALLEGHENY COALS.

UPPER COALS.

The two upper coals of the Allegheny formation outcrop at many points in this district, but apparently are too small for exploitation. In the section in the hill west of Willard (pp. 96–97) these two coals appear, the No. 8 or Hatcher coal about 32 feet above the Coalton, which has been dug into along the roadside, and the Zelda or No. 9

coal about 25 feet higher up. The intervals in this vicinity are apparently much less than those prevailing along Ohio River. At the head of Thompson Fork and the tributary flowing into it from the north the Zelda coal is thick enough to be worked for local use, and the following section was measured near the head of the main fork. (See also section 1, fig. 14.)

Section of coal No. 9, near head of Thompson Fork.

	Inches.
Sandstone.	
Bone	8
Coal	26
Fire clay.	

COALTON COAL (NO. 7).

Geologic position.—In the northern part of the district the Coalton coal is of considerable economic importance. Its occurrence here is merely the southwestern continuation of this coal in the Chesapeake and Ohio Railway district. About Willard it is found at 65 to 90 feet above the top of the Pottsville. The former measurement was obtained in the hill west of the town; the latter is the more usual interval. The coal bed occurs 50 feet above the fire clay at the Vanport limestone horizon at the north end of the town, about 30 feet above the Winslow coal, and 180 feet below the Cambridge limestone. Owing to the persistence and broad distribution of the Cambridge limestone it will serve as an excellent base from which may be calculated the depth below the surface of the Coalton coal well up on the headwaters of the numerous smaller creeks flowing into Little Fork. It is quite possible that deviations from the interval measured at Willard will be found.

Extent and development.—About Willard and north of Webbville the Coalton coal has been opened and worked at many places. In this vicinity it outcrops well down in the hills so that tipples may be conveniently run out to the main line of the Eastern Kentucky Railway or to short spur tracks. It outcrops in the hills between Straight Creek, Belle Trace Creek, and Lost Branch, disappearing below drainage level on Lost Branch near the mouth of Crooks Creek. A large body of valuable coal still remains untouched in these hills, and east of the points where it goes below drainage level no shafts have ever been sunk to reach it. Numerous country banks show this coal to be of fair thickness to points about a mile above the mouth of Belle Trace Creek and about a mile above the mouth of Lick Branch, west of Willard. South of Webbville the coal is present in the hills along Caney, Dry, and Equal forks, rising to the south. It has never been opened in this region. West of Dry Fork and Cherokee Creek the rise is so great that the coal is found only

near the tops of the hills, and consequently in small bodies. found in the ridge between Equal Fork and Blaine Trace B and to the west in the ridge between Little Fork and Blaine Branch, where 3½ feet of cannel coal is reported; it is presen in the hills north of Hurricane Creek. West and northwest oi lard the beds rise so steeply that the Coalton coal is present here and there in the tops of the highest hills, as, for instance, head of Field Branch and Johns Branch.

The center of development of this bed lies about Willar Webbville and at or near the mouth of Lost Branch, Lick Bı and Belle Trace Creek. The only large commercial operati this bed is that of the Eastern Kentucky Railway on Lost (

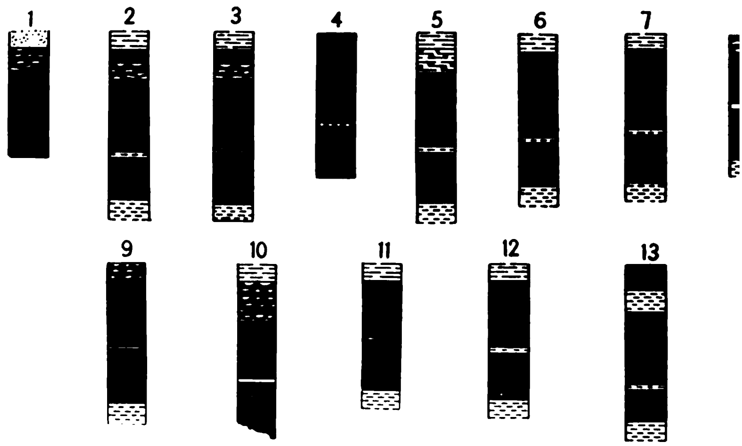


FIG. 14.—Sections of Zelda and Coalton coals. Zelda: 1, Head of Thompson Fork. ton: 2, East Kentucky Railway mine, Partloe (Mayapple post-office), Lost Bra James H. Williams, Lost Branch; 4, A. E. Fauson, Lost Branch; 5, southern Willard; 6, east of Willard; 7, east of Willard (Ashley); 8, 9, mouth of Bell Creek; 10, on Little Fork, north of mouth of Lick Branch; 11, near mouth Branch, west of Willard, on small tributary from the north; 12, Lick Branch, Willard; 13, head of Davies Branch (Ashley). Scale, 1 inch = 5 feet.

This company formerly mined this bed on an extensive scale of Willard, but at present all the old mines are shut down. the economic map an idea of the extent of this coal above dra may be readily obtained.

Character.—The thickness of this coal may be seen from th tions in fig. 14. It will be noted that the coal shows great unifo in its division into benches and also in the thickness of benches, and, though not indicated in the figures, the charact the coal in the different benches is also uniform. On Lost Branc at the head of Davies Branch where measurements were made benches are developed (sections 2, 3, and 13, fig. 14.) The top is from 4 to 7½ inches thick and is not worked. In the immedia cinity of Willard only two benches were noticed (sections 5, 6

7, fig. 14). The upper bench is about 2 feet thick, grading into bony coal at the top; the lower bench is usually a little more than a foot thick and is separated from the top bench by an inch or two of clay or shale. Near the mouth of Belle Trace Creek the upper bench seems to thin considerably and to range where measured from 15 to 20 inches in thickness (sections 8 and 9, fig. 14), and the lower bench, which is about 16 or 17 inches thick, is comparable in thickness with this bench near Willard. On Lick Branch, west of Belle Trace Creek, the sections obtained are about the same as those seen on the latter stream. The total thickness of these two worked benches rarely reaches 45 inches and averages most commonly about 3½ feet. From 40 to 45 inches of workable coal in the upper two benches may therefore be considered a maximum for this bed. From these thicknesses it thins out to nothing at some places where rolls in the roof and horsebacks occur.

The roof is as a rule fairly massive shale of variable thickness, usually capped by a very massive sandstone. The immediate roof is generally bony coal. The foreman of the Eastern Kentucky Railway mine at Partloe reports that the roof gives little or no trouble. Falls are rare, but posts are used. The floor is clay, but so far as known it is not mined for economic purposes.

The coal is bituminous. The upper bench is soft and full of charcoal partings; the lower bench is hard and splinty. Both are worked and shipped, the bone and clay partings being picked out by hand. Mining is fairly difficult.

The composition of this coal is illustrated by the analyses given on page 71. These figures are for the most part those of coals collected in the region about Rush, but analyses 11 and 12 represent samples collected from Lost Creek and west of Dry Fork near Willard and may be taken as typical of the coal in this vicinity. The application of this coal to iron making has been treated at some length in the discussion of its chemical character in the Chesapeake and Ohio Railway district (pp. 70–73) and will not be considered further here. It is not a coking coal, the output of the Eastern Kentucky Railway mine at Partloe being used exclusively along the railway for steaming and domestic purposes, for which it is admirably adapted.

WINSLOW COAL (NO. 6).

Extent and development.—The next lower coal corresponds with coal No. 6 of the Kentucky series and has been described in the section on the Chesapeake and Ohio Railway district under the name Winslow coal, owing to its fairly extensive exploitation at Winslow. Here, as in the district just referred to, it occupies a position between the Coalton coal above and the Vanport ("Hanging Rock") lime-

stone below. In the district north of Daniels Creek, Lawrence County, and on the ridges east and west of Blaine Trace Branch and at the head of Ison Creek, Elliott County, it is usually from 45 to 60 feet above the Vanport limestone, and as this limestone is very near the top of the Pottsville or Homewood sandstone, the same interval may serve also when the coal is referred to the latter horizon. About Willard, near the fire-clay mines in the northern part of the town, the smut of this bed was noted about 20 feet above the fire clay associated with the Vanport limestone and about 30 feet below the Coalton coal. West of the town it is about the same distance below this coal and above the Vanport limestone. Its identification in and about Willard is easy, as the red limestone ore overlying the Vanport limestone has been extensively worked at this place in the past. The coal is broadly distributed.

Though it outcrops in all the hills about Willard, it has never been worked and nothing can be stated definitely as to its character. It is probably too thin to be of any great value. Its bloom was noted in the hills skirting Dry Fork, Equal Fork, and Blaine Trace Branch. At the head of Equal Fork and Perkins Branch it is of workable thickness, and at a few country banks the coal is being opened. In this locality it will repay careful prospecting, for the underlying coal also is a most valuable bed, and should the Eastern Kentucky Railway be extended southward from Webbville to Blaine it would pass near enough to the heads of Perkins Branch and Equal Fork to make the coal in this locality of probable commercial importance. South of this point very little is known about it, but it should be found in the hills northeast of Canes Creek and in the ridges bordering Irish and Cherokee creeks. In the hills north of Daniels Creek and west of San Branch it has been opened and worked in a small way. On Brush Creek, south of the Elliott-Lawrence county line, this coal has been opened by J. Porter and is sufficiently thick to be worked in a local way. In the hills north of Mount Savage it seems also to be fairly persistent. At the head of Ison Creek, west and northwest of Stephens, Elliott County, a cannel coal is found about 50 to 60 feet above the top of the Pottsville and is referred to this horizon. It has been opened by L. A. Clark, W. B. Boggess, Isom Ison, and others in this region. This is the only known occurrence of cannel coal at this horizon. Northwest of Willard, near the hilltops at the heads of Johns Branch and Field Branch, this coal is present, but the area which it covers is small, owing to the steep rise of the beds to the west.

Character.—The sections of this coal obtained are so few in number that no reliable generalizations can be made regarding its physical character. Neither can it be stated that their paucity is an index of the thinness or poorness of the coal, for about the head of Equal Fork

and Perkins Branch and in the hills west of Dry Fork a considerable body of this coal exists in workable thickness. The area underlain by it is fairly comparable with that underlain by the Vanport limestone, which is indicated by the red line on the economic map (Pl. I), but as the coal lies somewhat higher in the hills its area will be slightly smaller than that of the limestone. As judged by sections 1 and 4, fig. 15, this coal is fairly comparable in this immediate locality with the same bed in the Chesapeake and Ohio Railway district. It carries three benches, separated by thin partings of bone or fire clay. The two top benches are soft bituminous coal; the lowest bench is hard splint. In this immediate territory the roof is shale and the floor clay. Little is known about the coal to the west, except along the edges of the quadrangle west and northwest of Stephens and north of Fielden. In this region the coal is largely cannel. Sections obtained here also show three benches (section 3, fig. 15). This coal has been opened in the hill south of Brush Fork by L. A. Clark

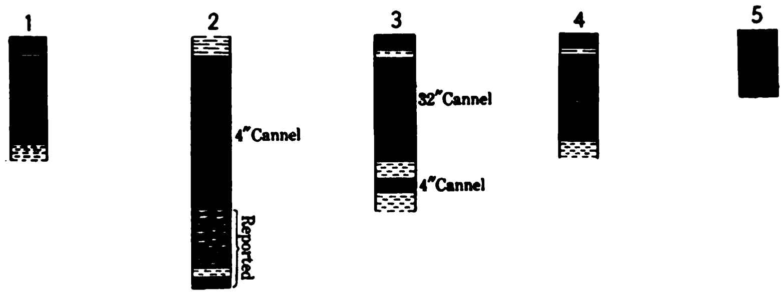


FIG. 15.—Sections of Winslow coal (Kentucky No. 6). 1, W. M. Clark and A. C. Campbell, head of Perkins Branch; 2, 3, head of Ison Creek (Ashley); 4, Dry Fork; 5, ridge between Equal Fork and Blaine Trace Branch. Scale, 1 inch = 5 feet.

and W. B. Boggess, and at Mr. Clark's bank it was reported 4 feet thick. Nothing is known of its character outside of the inconsiderable area bounded by Little Fork, Brush Fork, and Critches Creek, and in this district the acreage of cannel coal is not large, owing to its position very near the hilltops. It is, however, a valuable cannel coal, which will be worked in the future when cheaper transportation facilities are obtainable.

CAT CREEK COAL (NO. 5).

Extent and development.—The next lower coal is the most important coal in this district. It reaches its greatest thickness along Dry and Caney forks and Cherokee Creek and in the hilltops northwest of Willard, at the head of Johns Branch. It is the lowest coal in the Allegheny formation in this area and closely underlies the Vanport limestone. If it were correlated with one of the Pennsylvania or Ohio coals it would probably correspond to either the Brook-

ville or the Clarion; certainly not with any of the Kittanning coals, for these are all above the Vanport limestone. In this district little difficulty will be experienced in identifying this coal bed. Its position 20 feet or so below the Vanport limestone and on or near the top of the Homewood sandstone, which along Cherokee, Dry, and Caney creeks is very massive, should serve at once to locate it. This coal bed without doubt corresponds to coal No. 5 of the Kentucky Geological Survey. Its occurence in this district may with a fair degree of certainty be regarded as the western continuation of the coal occurring on Cat Creek, and so this name is used in this district. It has been carefully prospected in the hills lying about the head of Cherokee Creek, Dry Fork, and Equal Fork, and along Caney Fork well toward its mouth. It is present in the hills bordering Dry Fork and dips rather steeply to the north, disappearing below

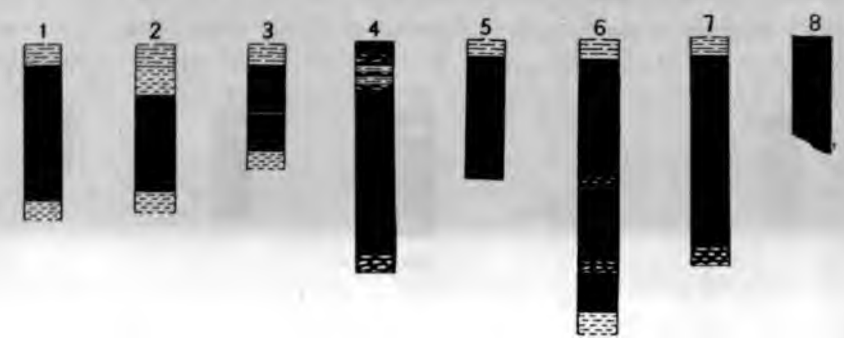


FIG. 16.—Sections of Cat Creek coal (Kentucky No. 5). 1, J. C. Webb, Caney Fork; 2, James Bryant, Caney Fork; 3, Henry Campbell, Caney Fork; 4, J. A. Young, head of Cherokee Creek; 5, James Wheeler, ridge east of Backbone; 6, 7, James Adams, head of Johns Branch; 8, J. C. Johnson, near head of Equal Fork. Scale, 1 inch = 5 feet.

drainage level before Webbville is reached. The same dip in the beds also causes its disappearance below drainage level before it reaches the mouth of Caney Fork. It is present in the ridge between Blaine Trace Branch and Equal Fork, and where seen near Backbone it is a thick coal bed of excellent quality. Its position is indicated by a bloom at many places in the ridge lying still farther to the west between Little Fork and Blaine Trace Branch. The southernmost point where its bloom was seen is in the hills just northeast of Blaine, but nothing is known of its character here. A large territory is underlain by this valuable coal in the region about Caney Fork, in the hills along Dry Fork and Cherokee Creek, in the hills between Equal Fork, Blaine Trace Branch, and Little Fork, and possibly south of Perkins Branch. Northwest of Willard this coal bed also appears in the hills and has been opened at a few places at the head of Johns Branch. At the banks of James Adams (sec-

tions 6 and 7, fig. 16) and John W. Barber the coal is comparable in thickness with the coal seen at the head of Cherokee Creek.

No attempt has been made to develop this coal on a commercial scale, though the construction of a spur track up Dry Fork is apparently a simple matter and such a spur would tap a large body of coal.

Character.—Measured sections of this coal are given in fig. 16. The sections given for this coal on Caney Fork were measured in small country banks and very near the outcrop and it is possible that they may not represent the true thickness of the coal. As seen on Caney Fork, the coal will probably average between 3 and 4 feet in thickness. As a rule the roof of the coal here is shale.

At the heads of Dry Fork and Cherokee Creek and to the west at the heads of Perkins Branch and Equal Fork the coal attains its greatest development in this district. At the J. A. Young mine, on a small creek entering the head of Cherokee Creek from the east, more than 4 feet of excellent clean coal was measured (section 4, fig. 16). From this mine a large block of coal representing the entire thickness of the main workable bench was taken to the Louisiana Purchase Exposition at St. Louis. At some points in the mine a lower bench, less than 1 foot in thickness, is reported, but this is not everywhere present. As a rule the roof is shale and the floor is bone passing into clay. In the ridge between Equal Fork and Blaine Trace Branch, a short distance east of Backbone, Mr. Ashley measured 38 inches at a bank owned by James Wheeler. It was reported that the usual thickness is 3½ feet. Mr. Ashley also measured 30 inches of coal in the ridge west of Equal Fork at the bank of J. C. Johnson, but 3 feet were reported to him.

The Cat Creek is a bright, lustrous bituminous coal, containing streaks of harder coal with probably some splinty layers. Without much doubt it will serve well for steaming and domestic purposes, but its efficiency as a coking coal has not yet been determined. It was used to supply the engine running the drill which bored a hole 2,000 feet deep near J. A. Young's residence at the head of Cherokee Creek, and it gave splendid satisfaction as a steam generator. From the fact that it separates into rectangular blocks of fair size and may be removed from its position in blocks the thickness of the entire main bench, it may appropriately be classed among the block coals. The following analysis was made by the Kentucky State chemist:

Analysis of coal No. 5 from J. A. Young's bank at head of Cherokee Creek.

Moisture	7.04
Volatile matter	36.88
Fixed carbon	53.72
Ash	2.36

The analysis shows this coal to be of very high grade. The moisture is rather high, but ash is low. No sulphur is given, but this constituent was probably not determined, as it is quite certain that some sulphur is present.

Economic aspects.—The marketing of this coal is an important consideration. The Eastern Kentucky Railway has extended its line as far south as Webbville, but under present conditions this does not materially help the exploitation of coal at the head of Dry Fork and Cherokee Creek. To get this coal to market it will be necessary to extend the railroad as far as the head of Dry Fork at least. This can be easily and cheaply accomplished, owing to the easy grade and absence of sharp curves on Dry Fork. Should the road be continued to Cherokee Creek, the divide would probably be tunneled. It may not be expedient to do this, for the bulk of the coal could be readily tapped by spur tracks from the main line up Dry Fork. It is generally understood that the Eastern Kentucky Railway proposes to extend its tracks as far south as the town of Blaine.

POTTSVILLE COALS.

UPPER STINSON COAL (NO. 4).

Geologic position.—In this district the Upper Stinson coal, though widely distributed, can not be classed among the important beds except locally. It has been stated that it is the highest coal in the Pottsville formation and that it occurs directly below the massive sandstone member (Homewood sandstone) forming the top of the formation. Its position below the top of the Homewood sandstone and hence below the Vanport ("Hanging Rock") limestone is variable, depending on the thickness of the Homewood, which is also variable.

About Willard the Homewood sandstone is massive, though not more than 30 to 40 feet thick. In the hills bordering Dry Fork and Cherokee Creek it seems to be less than 50 feet thick, but to the west it is thicker, at many places from 80 to 110 feet. At the heads of Justice, Leadenham, Hilton, and Wells branches and farther south in the region about Backbone and north of Stephens it is 110 feet or even thicker. South of Backbone and Stephens it becomes thinner again. At the head of Wiley, Collier, and Knob branches this member is unusually massive. Thus the Upper Stinson coal occupies a variable position with reference to the top of the Homewood sandstone, occurring usually from 40 to 110 feet below it.

Extent and development.—The coal is broadly distributed in this district. In its northern part it is present in the hills at the heads of Huff Creek and Field and Johns branches. An opening belonging to Silas Walker west of the head of Field Branch showed this coal

to be of workable thickness. The section measured is given in fig. 17 (section 1). On most of the waters of Blaine Creek and Little Fork the bloom of this coal bed shows, but few openings on it were observed, the presumption being that as a rule it is not workable. On Hilton Branch a coal regarded as the equivalent of this coal appears to be chiefly cannel. About a mile from the mouth of the branch on its north side, about 200 feet above the creek bed, there are two openings. At the one nearer the mouth of the creek, on the farm of Elijah Sturgill, 9 inches of coal were seen with more below, capped by 6 inches of shale overlain by very massive sandstone. Mr. Sturgill, jr., reports the usual thickness of the cannel coal to be about 3 feet with less than a foot of bituminous coal overlying it. Farther up the creek, on the land of William Corey, a section of the same bed was measured, and is represented in section 3, fig. 17. Mr. Corey reports

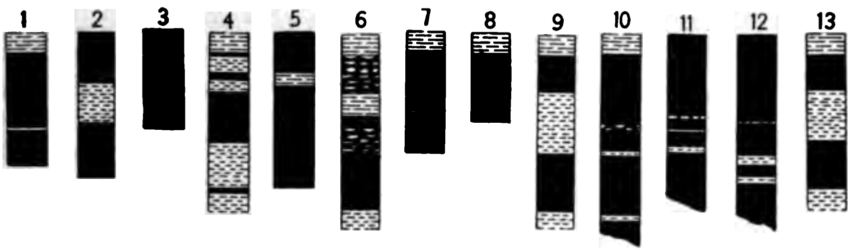


FIG. 17.—Sections of Pottsville coals. Upper Stinson coal (Kentucky No. 4): 1, Silas Walker, west of head of Field Branch; 2, northeast of Sarah (Ashley); 3, William Corey, Hilton Branch. Lower coals: 4, F. E. Holbrook, Right Fork of Blaine Creek; 5, A. T. Boggs, Right Fork of Blaine Creek (reported); 6, W. H. Lyons, Right Fork of Blaine Creek; 7, Levi Kitchen, Dry Fork; 8, head of Leadenham Branch; 9, J. N. Sparks, Halton Branch, west of Fielden (Ashley); 10, 11, 12, Robert Green, Halton Branch, west of Fielden (Ashley); 13, J. M. Green, head of Little Fork, west of Sarah. Scale, 1 inch = 5 feet.

29 inches of cannel as a maximum. The cannel coal was not seen north or south of Hilton Branch.

The coal in this district, aside from the cannel phase just described, is of the usual soft, lustrous character, in many places containing bands of harder splint.

LOWER COALS.

The next lower workable coal in this district occurs in most places 160 feet below the top of the Homewood sandstone. It will be found in this position along Right Fork of Blaine Creek and on the streams which flow into it from the north and on the headwaters of Little Fork. Possibly the coal opened by R. T. Berry east of the town of Blaine belongs here also. It is a question whether this coal can be regarded as the exact equivalent of the Lower Stinson or Torchlight bed, but in the sense of its being the second workable coal in the Pottsville, counting from its top, it may be called for convenience

No. 3. A section obtained in the ridge south of Rockhouse Branch showed five small coal beds lying between the coal under discussion and what is probably the top of the Pottsville formation. The occurrence of so many coals between the so-called No. 3 in this district and the top of the Pottsville is probably not very widespread, although it is quite probable that there is more than one coal in this interval. These intermediate coals may be locally workable. The conditions here present a strong argument against adhering strictly to a system of numerals in correlating coal beds over broad areas.

This coal, as has been said, occurs 160 feet below the top of the Pottsville formation on Right Fork of Blaine Creek. In the northern part of this district it will be found at a less distance from this horizon, and at the head of Field Branch the interval can not exceed 80 to 100 feet. Here this coal is not of workable thickness, but it is of more than ordinary interest from the fact that it consists largely of cannel. A section measured on the farm of Silas Walker showed 12 inches of cannel underlain by 8 inches of ordinary soft, bituminous coal. South of this place a coal, probably the equivalent of this bed, has been opened at the head of Leadenham Branch by Jackson Wilcox. The coal here has a shale roof and measures approximately 2 feet (fig. 17, section 8). Near Backbone and Stephens it is found near the bed of the creek and has been worked on a small scale for local supply. No measurements of the coal were obtained in this vicinity. On Dry Fork, about 2 miles south of Webbville, it has been opened by Levi Kitchen near the bed of the creek, and the section shows about 2½ to 3 feet of coal containing small partings of bone in its lower half (fig. 17, section 7). This coal is highly esteemed in the immediate neighborhood for smithing and domestic purposes. South of Cherokee it will be found near road level above the massive sandstone outcropping near the bridge over the creek. It has been opened at several points in the vicinity of Fielden and Sarah, where it is called the "mud seam." On Canes Creek, Rockhouse Branch, Knob Branch, Equal Fork, and in the vicinity of Willard sections obtained from this coal show it to be badly broken, and, though an important source of supply for local purposes, it is a question whether a coal with so many partings can become of commercial importance in the near future. Except where the coal is of the cannel type, as observed near the head of Field Branch, in Carter County, it is of the same character as the rest of the coals in this district—namely, partly splint and partly soft, lustrous bituminous coal.

The Barrett Creek coal, or No. 1 of the Kentucky series, has been opened at a few points on Deer Creek, northwest of Willard, and near Rosedale. The coal on Deer Creek shows at the two points where measured a somewhat better section than it does on Barrett Creek. (Compare fig. 18, sections 1 and 2, with fig. 13, sections 3,

4, 5, and 6.) Its position, about 60 feet above the top of the Sharon conglomerate, which is prominent along Little Sandy River in this region, serves to identify it. At Mrs. Rebecca Tackett's this bed shows 3 feet of clean, bright, lustrous coal with no partings, but at the bank of William Herbelan, well up on the east fork of Deer Creek, though the coal is still about 3 feet thick, it contains a band of bony coal near its top (section 1, fig. 18). The coal opened at the mouth of Field Branch is referred to this horizon. It probably belongs in the group lying close to the top of the Sharon conglomerate, as is indicated by the section obtained in crossing the ridge from Deer Creek to Little Fork. This section again illustrates the objections raised in this bulletin to numbering coals. On the west side of this ridge at least ten small coal beds appear, any one of which theoretically may be thick enough to be commercially valuable at some place. On the east side of the ridge seven coal beds were counted, the lowest of which is the one referred to above as outcropping near the mouth of Field Branch. This coal has been opened by Walter Field, Robert Rucker, and others, the openings being at

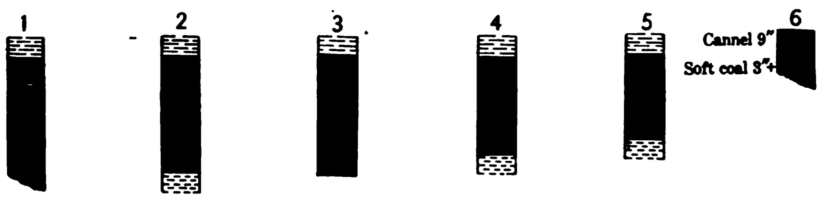


FIG. 18.—Sections of Barrett Creek coal. 1, William Herbelan, Deer Creek; 2, Mrs. Rebecca Tackett, Deer Creek; 3, Walter Field, Field Branch; 4, Robert Rucker, Field Branch; 5, R. T. Berry, Blaine; 6, J. W. Sparks, Sarah. Scale, 1 inch = 5 feet.

the base of the hills, but a few feet above the flood plains. At Mr. Rucker's coal bank about 2½ feet of excellent coal appears between a shale roof and fire-clay floor (section 4, fig. 18). At Mr. Field's over 3 feet of clean coal was seen, with a thin body of shale above, capped by a good sandstone. Mr. Field reports that some of the coal runs as high as 4 feet 4 inches, but that 3½ feet is a fair average. The position of this coal in the hills is such as to suggest the possibility of a large body of workable coal, the more so as it is believed that this coal may be the stratigraphic equivalent of that opened by Mr. Herbelan and Mrs. Tackett to the west of Deer Creek, which is known to be fairly persistent and of workable thickness. The position of this coal with reference to the railroad is favorable to its easy and cheap exploitation, and the slight westward rise of the beds in this vicinity should solve in large measure most of the difficulties encountered in the drainage of the mines.

The coal opened by R. T. Berry, southeast of Blaine and east of Hood Creek, may belong at this horizon. It measures 26 inches in

thickness and is worked for local use. The coals along Irish Creek, near its mouth, are referred to the lower horizons in the Pottsville. They are reported workable in one or two places, but the writer was not able to verify this information. These lower coals are here and there partly cannel. The coal measured by G. H. Ashley near drainage level at Sarah is considered to be near the base of the Pottsville; it was reported 28 inches thick, with a 12-inch bench of cannel 8 inches from its top.

The coal mined along Brushy Creek is one of the most important of the lower beds. It has been referred to at times as No. 1 or the Barrett Creek coal, but its position with reference to the Sharon conglomerate outcropping along Brushy Creek in the vicinity of Cordell leads to another interpretation. Below Cordell at the bank of A. J. Soard this coal is 180 feet above the top of the Sharon, a much greater distance than appears about the town of Blaine, or along Deer or Barrett creeks. It is strongly probable, therefore, that the coal on Brushy Creek is higher than the Barrett Creek bed. It may

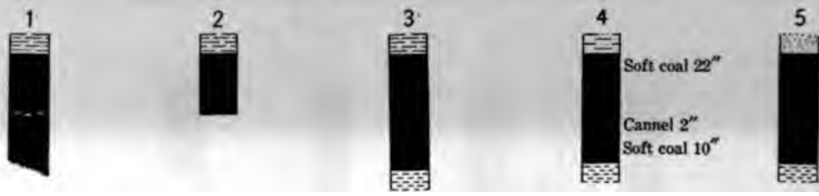


FIG. 19.—Sections of coal on Brushy Creek. 1, Two miles east of Blaine; 2, Simpson Steele, head of Brushy Creek; 3, Isaac Adams; 4, Garfield Moore; 5, near mouth of Big Branch. Scale, 1 inch = 5 feet.

correspond to No. 2 of the districts to the north, though without paleobotanic evidence such long-distance correlations have little value. Some of the coal along Brushy Creek contains a thin streak of cannel, as at the bank of Garfield Moore. It shows in general about 3 feet of coal, partly soft bituminous and partly splint. It appears to be persistent in the hills along Brushy Creek to the point where it disappears below drainage level about three-quarters of a mile above the mouth of Big Branch. It is an excellent coal for domestic purposes and furnishes all the inhabitants with fuel. The sections of this coal, measured by the writer, are given in fig. 19.

TECHNOLOGY OF THE COAL MINING.

Most of the mines in this quadrangle are small, none employing more than 75 men and very few averaging as high as 50 men daily throughout the year. The equipment is in most places comparatively simple. All the shipping mines are ventilated by means of furnaces, and drainage is usually natural, by means of ditches. In a few of the mines siphons are used for the drainage, and the occasional use

of hand pumps is reported. None of the mines were reported to be gaseous. In the majority the coal is picked with the ordinary hand picks, but machine mining is practiced at the Torchlight mine, Sullivan compressed-air drills being used.

The width of the entries, the distances at which rooms are turned, and the size of pillars left vary considerably in the different mines. The main headings are run usually 8 or 9 feet wide, and the cross headings are a foot or two narrower. Rooms are turned every 33 feet or thereabouts and vary in width, but most are from 20 to 25 feet wide. The custom seems to be to run the rooms 200 or 250 feet long. The pillars left are from 8 to 13 feet wide.

All the coal is carried from the mines by mules in cars with capacities ranging from 1,200 pounds to 1 ton. Most of the mines have the larger-size cars, but one mine reports the use of a car with a capacity of 1,300 pounds. All the mines are drifts. Most have the ordinary cradle tipple, but that of the Torchlight Coal Company is more elaborate, employing a shaking screen. Most of the coal is shipped as run-of-mine, but it is sometimes screened to suit the buyer. When this is done a small loss, usually not more than 5 per cent, is entailed.

Nearly all of the coal mined in the quadrangle is shipped to places along the local railroad lines. Much of that mined at Rush and Winslow goes to Ashland, where it is used at the furnaces or for domestic purposes. That mined on Lost Creek by the Eastern Kentucky Railway is likewise used along the line or by the railroad itself. The cannel mined by the Kentucky Cannel Company at Boghead and Hunnewell is shipped abroad, where it is used as a gas enricher. Some of the coal mined at the Torchlight mine is shipped to the Pacific coast and other western points.

STATISTICS OF COAL.[a]

The following figures give an idea of the magnitude of the coal industry in this area during the last five years. The figures represent tons of 2,000 pounds each.

Coal production in Kenova quadrangle, 1902–1906.

County.	Loaded at mines.	Sold or used locally.	Total.	Value.	Average price per ton.
1902.	*Tons.*	*Tons.*	*Tons.*		
Boyd	241,127	870	241,997	$193,479	$0.80
Carter	268,056	13,345	281,401	285,271	1.01
Miscellaneous[b]	3,686	586	4,272	5,335	1.25
	512,869	14,801	527,670	484,085	
1903.					
Boyd	245,491		245,491	220,686	.90
Carter	256,321	8,905	265,226	289,130	1.09
Miscellaneous	22,713	1,550	24,263	26,819	1.11
	524,525	10,455	534,980	536,635	

[a] Statistics were obtained from the records of the United States Geological Survey.
[b] Miscellaneous, in each year, includes Lawrence County, Ohio, and Lawrence County, Ky.

Coal production in Kenova quadrangle, 1902–1906—Continued.

County.	Loaded at mines.	Sold or used locally.	Total.	Value.	Average price per ton.
	Tons.	*Tons.*	*Tons.*		
1904.					
Boyd	69,067	28	69,095	58,304	[illegible]
Carter	241,088	3,942	245,030	259,384	1[illegible]
Miscellaneous	23,441	1,200	24,641	26,016	1[illegible]
	373,596	5,170	338,766	343,704	------
1905.					
Boyd	46,542	1,762	48,304	37,260	
Carter	138,135	7,034	145,169	144,448	1[illegible]
Miscellaneous	10,310	100	10,410	9,750	
	194,987	8,896	203,883	191,458	------
1906.					
Boyd	46,322	2,500	48,822	38,540	
Carter	154,482	4,266	158,748	144,899	
Miscellaneous	5,845	70	5,915	5,295	
	206,649	6,836	213,485	188,734	------

Production at country banks only and for local trade.

County.	1905. Tons of 2,000 pounds each.	1905. Value.	1905. Average price per ton.	1906. Tons of 2,000 pounds each.	1906. Value.	1906. Average price per ton.
Boyd	516	$456	------	3,284	$3,931	------
Carter	2,367	2,724	------	2,298	2,392	------
Elliott	473	638	------	272	355	------
Greenup	323	372	------	------	------	------
Lawrence, Ky	7,621	8,658	------	2,612	2,348	------
Lawrence, Ohio	------	------	------	2,020	2,525	------
	11,300	12,848	$1.14	10,486	11,551	$[illegible]

According to the reports of the State inspector of mines of Kentucky, the production of cannel coal and of coke from 66 ovens in this area for the years 1901 to 1904 was as follows:

Production, in short tons, of cannel coal and of coke, 1901–1904.

	Cannel coal.		Coke.
1901	11,203	1901	23,320
1902	11,339	1902	23,075
1903	8,341	1903	22,323
1904	2,780	1904	17,980

CLAYS AND SHALES.

INTRODUCTION.

The clays of the Kenova quadrangle will be described by horizons, as some are scattered over the entire area, and the description by districts would involve needless repetition. All the clays of northeastern Kentucky have been deposited by the agency of water and are hence called sedimentary clays. They may be divided with regard to both their age and their adaptability into two classes—(1) clays which were deposited in Carboniferous time and are more or less closely associated with coal beds, and (2) recent clays, that is,

those occurring in the present river and stream valleys. The former are by far the more important. For descriptive purposes the clays may be regarded as either plastic or nonplastic; the latter variety is also known as flint clay.

On pages 14–21 of this bulletin will be found a somewhat extended description of the beds in which these clays are found and the way in which they are classified according to their relative ages. The reader is referred to this preliminary description for explanation of many of the terms used in the following discussion. On page 29 also will be found a brief description of the clays, to which the general reader is referred. The following notes are intended for the use of those who are more particularly interested in the clay resources of this region, and hence the description will be given with considerable detail and will be accompanied by sections and analyses. The columnar section on the economic map will show the position of the more important clay horizons.

CLAYS IN THE CONEMAUGH FORMATION.

The clays highest geologically are in the Conemaugh formation. As a rule the plastic clays in this formation are the under clays of coal beds. The Conemaugh coal beds are irregular, both in distribution and in thickness, and the same is true of the associated beds of clay. Clay has been noted at a few horizons, but it is not worked at any place so far as known.

The shales in this formation are abundant and widespread. So far as known these have not been utilized, but it is certain that they are adapted to the manufacture of some types of building brick. They are present in the hills about Ohio and Big Sandy rivers and are conveniently situated with respect to transportation.

CLAYS IN THE ALLEGHENY FORMATION.

CLAY ASSOCIATED WITH VANPORT LIMESTONE.

The clay bed associated with the Vanport ("Hanging Rock") limestone easily outranks all the other clays in the Allegheny formation in distribution, quality, and quantity. This clay bed occurs near the base of the Allegheny; it usually lies from 10 to 40 feet above the top of the Homewood sandstone, or Pottsville formation, between coals Nos. 5 and 6. In the absence of coal No. 5 it may lie even nearer the Homewood sandstone.

Extent.—This clay bed is above drainage level at Coalgrove and Forestdale, Ohio, but the dip to the east soon carries it below drainage level. It has been opened and worked in the hills both east and west of Ashland and also north of Catlettsburg. The dip toward the center of the basin causes its disappearance near the mouth of Big Sandy River, and it does not reappear north of Louisa. From Louisa it occurs in the hills in a great arc, following the outer edge of

the basin and coming back to Ohio River near Ashland. Its horizon is also above drainage level to the east and southeast of Cassville, W. Va.

This economic horizon, the beds at which contain clay, iron ore, and limestone, is indicated on the map (Pl. I) by a red line. It will be understood that the clay is not necessarily workable at all points on this line. The flint clay, which occurs in small amount associated with the plastic variety, will be found a great help in the field in locating these deposits, for, owing to its indestructible character, small fragments of the flint clay usually remain near the outcrops. Its position near the top of the massive Homewood sandstone should serve as an additional help in locating it.

Development.—The following firms work this clay: Petersburg Fire Brick and Tile Company, Coalgrove, Ohio; Ashland Fire Brick Company, W. T. Johnson, and O'Kelly Brick Company, Ashland, Ky.; Weaver Pottery Company, Catlettsburg, Ky.; Willard Fire Clay Company and Frailey & Rice, Willard, Ky. Besides the mines of the above firms, numerous small openings which had been worked in the past and many prospects were located by the writer during this investigation.

Physical character.—The clay at the horizon of the Vanport limestone is plastic, except for the small band of flint clay. The plastic clay is of two grades, the high (No. 1), and the low (No. 2). The flint clay is of slight economic importance owing to its thinness. The two following sections, one measured by G. H. Ashley 1 mile west of Ashland and the other by the writer at Willard, give an idea of the associated beds:

Section of clay bed 1 mile west of Ashland (Ashley).

	Ft.	in.
Sandstone, light brown	20+	
Coal	2+	
Shale, light drab	2	
Clay, light brown	6	
Clay, dark drab	1	6
Clay, drab with scattered iron-ore concretions (Vanport limestone horizon)	2	
Shale, light drab, sandy	1	2
Shale, drab, ranging up to		8
Clay, dark drab to black, grading into light drab at middle	1	6
Clay, drab	3	
Flint clay		1–4
Clay, drab	3	6
Clay, dark drab, almost black		3
Clay, drab	8	

Four feet from the bottom of the lowest layer is about 1 foot of light drab flint clay, similar to the best of the Pennsylvania flint clays.

Section of clay bed at Willard, Carter County, Ky.

	Ft.	In.
Fire clay		4
Coal		4
Flint clay, bluish (reported)		4
Clay, dark, plastic	4	
Clay, light, plastic, harder than the above	2	
Vanport limestone:		
Iron ore, red (2 to 4 feet) } Limestone (4 to 6 feet) }	10	
Flint clay, thin band, formerly shipped to Olive Hill, Ky., and to Strasburg, Ohio.		

The Willard section differs from that at Ashland in having the ›rkable clay above the limestone, and not both above and below, in the section measured by Ashley and also in a section measured the writer at the clay bank of William T. Johnson west of Ash- ıd.

Section at the William T. Johnson clay mine, west of Ashland.

	Ft.	In.
Clay, dark	4	
Limestone ore (locally replaced by 4 feet of limestone), averaging		6
Bone, not always present		2
Clay, light drab	2	

The clay also occurs both above and below the limestone in the ening of the Petersburg Fire Brick and Tile Company at Coal- ›ve, Ohio, and the following section reported to the writer shows ›se conditions:

Reported section of clay bed at Coalgrove, Ohio.

	Ft.	In.
Clay, plastic	1	6–8
Clay, soft, plastic (No. 2)	5–6	
Limestone	4	
Clay (No. 1)	1	8

John Peters, president of the company, reports that the beds ›upy these relative positions for several miles to the west. In the stern part of Ashland, at the O'Kelly Brick Company's opening, e following section was measured:

ection of clay bed at the mine of the O'Kelly Brick Company, Ashland, Ky.

	Ft.	In.
Clay, upper, dark	4	6
Coal		4
Clay		3½
Coal		3
Clay	3	6

The siliceous clay given in the section (p. 117) at the base of the llegheny formation near Louisa and Cassville probably belongs ar this horizon. In the section measured at Cassville more than 6

feet of clay is shown, and in the section on the Chesapeake and Ohio Railway about 1 mile north of Louisa about 8 feet of very similar material was measured.

In some places clay at this horizon is suitable for making pottery. A section measured by P. N. Moore at Amanda furnace, about 4 miles northwest of Ashland, shows a layer of pottery clay. This section is as follows:

Section of clay bed near Amanda furnace.

	Ft.	In.
Soil	4	
Clay shale	6	
Coal		4
Clay (No. 2)	3	
Clay, pottery	4	
Clay (No. 1)	3	
Limestone ore		8
Top of Vanport ("Hanging Rock") limestone.		

The product mined near Amanda furnace was shipped to Cincinnati. The only company in this quadrangle using clay from this bed in the manufacture of pottery is the Weaver Pottery Company, located near Catlettsburg. Of the 6 feet of clay measured in the company's bank only the upper 3½ feet is worked, the lower part of the bed being too sandy to give satisfaction. The presence of limestone pebbles has also caused the company some annoyance. When subjected to the baking process the carbon dioxide in the limestone is liberated, causing little particles of the vessel to flake off, and thereby either ruining the vessel or making it of second grade.

Chemical character.—The character and color of the clay in the different benches is, as a rule, fairly uniform. The fracture is rather irregular, and the clay is somewhat hard, but becomes soft on exposure and afterward makes better brick. The following analyses indicate the chemical character of this clay:

Analyses of clay associated with the Vanport ("Hanging Rock") limestone.

	1.	2.	3.
Silica (SiO_2)	60.54	40.14	56.40
Alumina (Al_2O_3)	25.89	43.72	28.00
Ferric oxide (Fe_2O_3)	1.75	1.98	
Manganese oxide (MnO)	.26		
Lime (CaO)	.53	1.60	1.30
Magnesia (MgO)	.12		
Potash (K_2O)	1.85		
Soda (Na_2O)	.65		
Water (H_2O)	2.05	12.56	14.30
Loss on ignition	7.43		
Sulphuric anhydride	.12		
	101.19	100.00	100.00

1. Willard, Carter County, Ky. Analysis made at the structural materials testing laboratory, United States Geological Survey, St. Louis, Mo. C. H. Stone, analyst.
2. Upper stratum of clay at Vanport limestone horizon, Ashland, Ky. Robert Peter, analyst.
3. Lower stratum of clay in No. 2.

Analyses 2 and 3 were kindly furnished by the Ashland Fire Brick Company.

Applications.—As observed from the sections, most of the clay at this horizon is of No. 2 quality. It is used chiefly as a bond in the manufacture of fire brick and to a less extent for blast-furnace crucibles, boshes, coke-oven brick, etc. For the first-named purpose it is used by the brick companies at Ashland and Coalgrove. The product mined at Willard is shipped chiefly to Olive Hill, where it is mixed with flint clay to make a first-grade fire brick. The Willard fire brick is esteemed very highly by the clay men at Olive Hill. The Ashland Fire Brick Company has to import flint clay to make its high-grade refractory products. To make first-class refractory brick 67 to 80 per cent of flint clay is used, depending on the use to which the product is to be put, the remainder being plastic clay. For second-grade articles these proportions are reversed. It has been estimated that probably 500 to 700 pounds (according to the way the clay is used) will be sufficient to make 1,000 regulation 9-inch brick, when this clay is used alone as a binder. Its use in the manufacture of pottery has been referred to.

OTHER ALLEGHENY CLAYS.

Near North Kenova, Ohio, a clay was worked thirty years ago and hauled to Burlington and South Point, where it was used in making pottery. The old clay mines are now entirely fallen shut. The clay is 25 feet above No. 8 coal and directly below a massive sandstone, thus occupying a position near No. 9 coal. This correlation is strengthened by its distance of about 85 feet above the Sheridan coal. This is the only known occurrence in the area of a workable clay at this horizon.

At Cassville, W. Va., a flint clay has been prospected at a horizon lower than the above, in the hills north of the depot, by Frank Yates, of Louisa. It is found at an elevation of about 80 feet (barometric) above the tracks of the Norfolk and Western Railway, and about 100 feet below the base of the massive Mahoning sandstone near the top of the hill.

Section of Yates clay pit, Cassville, W. Va.

	Feet.
Cliff of brown, fine-grained, argillaceous sandstone.	
Shale, olive drab	5
Clay, drab, with numerous nodules of iron or lime, 2 to 4 inches in diameter, and distributed in lines	4½
Clay, drab, granular near crop, smooth farther back	1½
Clay, light drab, soft, plastic, smooth at back of pit, breaking with subflinty fracture, at crop apparently typical flint clay	2½
Clay, dark drab, hard, sandy	1
Clay, drab	3
Clay, brownish red	5

The same clay was also observed at a few points in the hills along Mill Creek and is reported 4 feet thick at one point. This flint-clay horizon is certainly worthy of very careful prospecting.

Other clays locally workable undoubtedly exist in the Allegheny formation. Many shale beds also appear promising and will probably be used in the future for paving bricks, sewer pipes, and other purposes where inferior material may be utilized.

CLAYS IN THE POTTSVILLE FORMATION.

SCIOTOVILLE CLAY.

In the Pottsville formation, as in the Allegheny, one clay bed stands preeminently above the rest as regards quality, distribution, and thickness. This is the Sciotoville fire clay of the Ohio Geological Survey reports, less commonly known as the Logan clay. It has been extensively mined at Sciotoville and Portsmouth, Ohio. It occurs a few feet above the Maxville limestone, but this limestone and the beds immediately above it are very sparsely distributed in this quadrangle. On the map (Pl. I) the red line drawn on Everman Creek, Carter County, just at the western edge, and the red line on Tygarts Creek indicate the extent of this horizon above drainage in this area and also where it may be looked for. On Everman Creek, a short distance above the residence of David Childers, 4 to 6 feet of nonplastic clay shows and has been mined. A short distance below Mr. Childers's house the limestone outcrops in the road, apparently directly below the massive Sharon sandstone. The clay was not observed here. It was reported to G. H. Ashley as being 5 feet thick and resting directly against the limestone on North Fork of Oldtown Creek, and as usually being present without the limestone in the hills east of Tygarts Creek. West of Tygarts Creek the limestone is reported as generally present, but little seems to be known of the clay.[a] This horizon may be looked for along the western outcrop of the coal measures, occurring, as it does, at the base of this series of rocks. Where present it will usually be found a few feet above the Maxville limestone or, in the absence of this bed, occupying a similar position above the sandstones of the Waverly. Though its outcrop area in the Kenova quadrangle is extremely small, a few miles to the west its horizon is above drainage level in nearly the entire valley of Tygarts Creek. At Olive Hill, in Carter County, it is now extensively worked by the Portsmouth Harbison-Walker Company and the Olive Hill Fire Brick Company, and it shows the following section at one of the openings of the former firm:

Section of clay bed at Olive Hill, Carter County, Ky.

	Ft.	in.
Coal		2-6
Clay, No. 3	1-9	
Clay, drab flint (No. 1)	1-9	
Clay, "semihard" (No. 2)	1-5	

[a] These statements refer to the territory within the Kenova quadrangle.

	Ft.	In.
"Pink eye"	3	
Shale, blue	1	6–8
Iron ore		4–8
Top of Maxville limestone.		

This order of superposition is usually maintained in this district. It will thus be seen that there may be four distinct varieties of clay present in this noted bed. Of these the nonplastic or drab flint clay is by far the most important and becomes the basis of refractory materials of the highest grade. The layer known as "semihard" is on a par with the clay at the horizon of the Vanport ("Hanging Rock") limestone, already described, though by some of the clay workers the Vanport limestone clay, at least at some points, is considered superior. The "semihard" is a plastic or No. 2 clay and is mixed with the flint clay in various proportions, depending on the desired quality of the product. No. 3 clay is also plastic, but of inferior quality to No. 2, while that called "pink eye" may be worked up into bricks, but the product is off color. The following analyses indicate the very high grade of the flint clay at this horizon, the percentages of silica and alumina approaching the theoretical values in kaolinite:

Analyses of Sciotoville flint clays of Kenova quadrangle.

	1.	2.	3.
Silica (SiO_2)	50.95	48.56	46.75
Alumina (Al_2O_3)	39.49	37.471	38.17
Iron oxide (Fe_2O_3)		Trace.	Trace.
Lime (CaO)		.112	.17
Magnesia (MgO)	.28	Trace.	Trace.
Phosphoric acid (P_2O_5)		.225	
Potash (K_2O)	.30	.289	Trace.
Soda (Na_2O)		.283	
Water (H_2O)	9.18	[a] 13.030	14.03
	100.20	100.000	99.12

[a] Expelled at red heat.

1. Sciotoville fire clay. N. W. Lord, analyst; Ohio Geological Survey, vol. 7, 1893, p. 58.
2. Ridge between Grassy and Three Prong creeks, Carter County, Ky. Sample collected by P. N. Moore; Robert Peter, analyst; Report on eastern coal field: Kentucky Geol. Survey, vol. C, p. 10.
3. Near Olive Hill, Carter County. Analysis furnished by Ashland Fire Brick Company.

OTHER POTTSVILLE CLAY BEDS.

There are other clay beds below the Homewood sandstone, but they have not come into prominence. One of these is the clay associated with No. 4 coal, which lies under the Homewood sandstone. This coal and its underlying clay outcrop in the eastern part of Ashland, and the coal has been worked in a small way at many places on the road approaching the cemetery. In the summer of 1905 the O'Kelly Brick Company opened the coal and clay and began to utilize the clay at

its brick plant in the eastern part of the city with satisfactory results. The following section was measured at the opening:

Section of coal and clay below the Homewood sandstone in the eastern part of Ashland, Ky.

	Ft.	In.
Sandstone, massive.		
Coal	1	6–7
Clay		10
Coal		8–9
Clay	2½–4	

The same bed of coal, with its underlying clay and clay parting, also occurs on Catletts Creek, and there is no reason why this clay should not be exploited in connection with the coal here, unless it be its relatively great distance from transportation.

In the hills about the head of Johns and Field branches, Carter County, a few prospect holes have been made on a bed of clay lying a few feet below the Homewood sandstone. This position is similar to that of the clay occurring in the eastern part of Ashland and on Catletts Creek. On the land of Judge John W. Barber 4 feet of sandy clay was measured at a prospect which had not penetrated the bed far enough to reveal its real character and thickness. This bed should be further prospected in these hills.

RECENT CLAYS.

The recent clays are found in the flood plains of the rivers and small streams and are very common, many small streams having flood-plain deposits which extend well up to their heads. These flood-plain clays are very erratic in their distribution in the valleys of the larger streams, and there is no means of pointing out where they are most likely to occur. They range in thickness from 1 foot to over 4 feet. Often in working a clay bed a sandy clay is encountered, which makes " dead " brick. These streaks of sand are also utilized by the brick manufacturers, but for certain purposes this sand has been found unsuitable owing to the intermixture of particles of coal. The deposits worked at present are confined to the valley of Ohio River in the vicinity of Ashland, where there is a local market, cheap coal, and transportation facilities. The flood-plain clay is used chiefly for ordinary red building brick, though it is adapted to the making of tile, shingles, fireproofing, etc. It is made into brick at the Means-Russell plant, west of Ashland, and by the J. J. Gates Company and the O'Kelly Brick Company in the eastern part of the city. The smaller flood plains contain clays which perhaps will not compare in quality with those of the larger river valleys, but which may be worked up into material suitable for local country use. F. R. Bussey has utilized such material from the flood plain of Harriet Branch of Little Blaine Creek. The deposit is here only 4 feet thick, but it illustrates the possibilities existing on all the smaller creeks. Flood-plain

deposits along Big Sandy and Little Sandy have not even been prospected. Undoubtedly valuable deposits of clay exist along both these streams, and they may be utilized later for common and pressed brick, tile, paving brick, sewer pipe, etc. Experiments having in view the adaptability of these flood-plain clays to the various purposes enumerated above should certainly be carried out.

TECHNOLOGY AND STATISTICS.

All the clay mines in this area are drift mines, in which the workings are very irregular. The mines are drained either naturally or by siphon and pump, and ventilation is either natural or by furnace. In mining the clay the upper part of the bed is usually shot out by powder or dynamite and the lower part pried up. The clay is hauled from the mine in ordinary mine cars drawn by mules. The following table will give an idea of the magnitude of the clay industry in this region during the last five years:

Statistics of clay products in the Kenova quadrangle, 1902–1906.

Year.	Quantity of brick, including fire, vitrified, and common building brick.	Total value.*
	Thousands.	
1902	10,587	$133,633
1903	12,736	179,221
1904	14,861	92,354
1905	11,574	128,400
1906	12,826	152,631
	62,584	686,239

* These figures include values of pottery also. The figures were obtained from the files of the United States Geological Survey.

The seeming discrepancies in the above figures are due to variations in the amounts of fire brick and ordinary red building brick produced. For instance, the figures indicate a very unusual production of the more valuable fire brick in 1903, followed by a falling off in this commodity and an increase in the production of the less valuable ordinary red building brick in 1904.

It has been found inexpedient to separate the statistics of the fire brick and other varieties, owing to the small number of manufacturers of fire brick during some of the years. For the same reason it has been thought inadvisable to tabulate the statistics of the production of raw clay. The United States Geological Survey has figures for this product for only 1905 and 1906, and the industry is yet in its infancy. It is probable that it may never grow to great proportions, as most of the clay will continue to be worked up near the mines to satisfy home consumption. During 1905 and 1906, 20,168 tons of

clay, of 2,000 pounds each, valued at $11,855, were shipped from the clay mines. All this has come from the clay at the horizon of the Vanport ("Hanging Rock") limestone.

MARKET.

The market for the clay products of this area is rather local. Most of the red building brick is used at home or shipped to the neighboring towns in West Virginia and eastern Kentucky. The fire brick is either used locally at the furnaces in Ashland or shipped up or down Ohio River, along which there is considerable demand for such material.

LIMESTONES AND IRON ORES.

INTRODUCTION.

The iron ores of the Hanging Rock region of Kentucky were of great importance in the seventies and eighties, but owing to the introduction of cheaper ores from Alabama and the Lake Superior country, and to the gradual disappearance of the forests on which the charcoal furnaces depended, the iron industry of this region has declined, and at present no furnaces depending on the local ore supply are in operation. (See Pl. V.) The ore diggings are now fallen in, and in many places have entirely disappeared, so that it is not easy to trace them. The following descriptions are therefore necessarily brief, especially those relating to the block and kidney ores, which at present are not worked at all. For fuller descriptions of the iron ores as a whole the reader is referred to P. N. Moore's report in vol. C of the Kentucky Geological Survey, from which the writer has freely drawn.

Where the iron ores are better known than their associated limestone beds the description of the limestones is made subsidiary.

IRON ORES.

GENERAL OUTLINE.

The iron ores of this region are chiefly earthy carbonates, spathic ores, or siderites, but on the outcrop and at variable distances in, depending largely on the porous or nonporous character of the roof, the ores have been altered to the hydrous ferric oxide, limonite. The ores may be classified as follows: (1) Limestone ores, (2) block ores, (3) kidney ores, (4) black band ores.

Limestone ores are those which occur upon or very near the top of a limestone stratum. In many localities they occupy a broader field than the limestone, but the term is still applied if the ore occurs

A. ABANDONED PRINCESS FURNACE.

B. ABANDONED BELLEFONT FURNACE, SHOWING RUINED HEAD WORKS.

near the stratigraphic position of the limestone. In eastern Kentucky these ores occur at two horizons—the lower associated with the Maxville and the higher with the Vanport limestone. Owing to their purity, uniformity, richness in iron, and ease in working they have been among the most highly valued of all the iron ores in this region.

Block ore and kidney ore are so called from their physical appearance. The former cleaves into more or less square or rectangular prisms when raised from its bed; the latter derives its name from its peculiar kidney shapes. Both varieties occur as unaltered carbonates or siderites, except where oxidized to limonites on or near the outcrop. The term "black band" is applied to beds of carbonate of iron with more or less bituminous and earthy matter associated.

Geologically these ores occur throughout the Carboniferous rocks in the Kenova quadrangle, but the most important are found in the two lower formations, the Allegheny and the Pottsville. These iron ores are all bedded deposits in the sense that they occur at fairly well-defined geologic levels, which are persistent over broad areas. The skeleton section (fig. 20) shows their relative position.

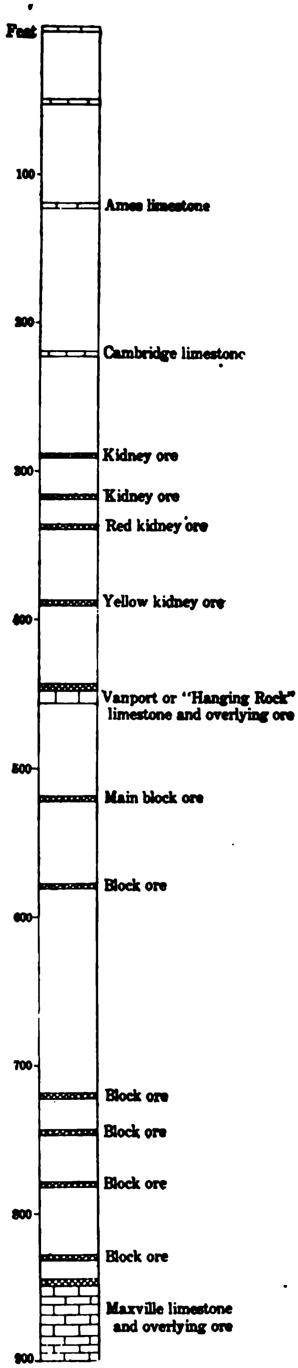


FIG. 20.—Skeleton section showing relative position of limestone and iron ores.

LIMESTONE ORES.

VANPORT LIMESTONE ORE.

Geologic position.—The higher of the important limestone ores is that associated with the Vanport ("Hanging Rock") limestone and hence known as the Vanport limestone ore. It is often known also as the red limestone ore and in the Kentucky Geological Survey reports as the "Ferriferous" limestone ore. It occurs from 10 to 40 feet above

the top of the Pottsville, between coals Nos. 5 and 6, the latter being known about Ashland as the "limestone coal" on account of this fact.

Extent.—The Vanport ore horizon is found in both Ohio and Kentucky. In Ohio its outcrop area is small in this quadrangle, but it is very extensive to the north and west. As it lies so near the top of the Pottsville, structure contours drawn on the latter hypothetical plane apply equally well for this ore horizon and for its associated limestone and plastic clay. Moreover, the red line drawn on Pl. I to represent the outcrop of the clay represents equally well the iron ore and limestone. Immediately south of Ohio River its western limit is beyond the border of this quadrangle and is reported by Moore as being about a mile below Amanda furnace, a few miles northwest of Ashland. The main western outcrop in the Kenova quadrangle appears at its northern edge in the hills between Little Sandy River and East Fork and continues southwestward to the point where the boundaries of Elliott, Lawrence, and Carter counties come together. From this point the general trend of the outcrop is southeastward beyond Big Sandy River. In Boyd, Greenup, and Carter counties much of the ore at this horizon has been removed along the outcrop, but good ore was seen in Lawrence County near the town of Blaine and in the hills between Adams and Prosperity.

Character.—Though the red line indicating the position of the Vanport limestone and its associated clay and iron ore has been drawn continuously on the economic map, this by no means indicates that the ore and limestone will be found continuously. On the contrary, it is known that the limestone and the accompanying ore are in many places not present, and where present are locally variable in thickness. The ore rests on the top of the limestone, and the bounding surface between ore and limestone, according to Moore, is very irregular, being full of little ridges and depressions. The limestone ranges up to 8 feet in thickness, but may be absent where the ore is present. The ore itself ranges from a few inches to a few feet in thickness, but may be pockety and the pockets may be several feet thick. The section of fire clay at Willard, Carter County, and at William T. Johnson's clay mine, west of Ashland, and Moore's section at Amanda furnace illustrate the thickness and associations of the ore and limestone.

The limonite ore occurring at the outcrop is usually brown or red, more commonly the latter, and in general dense and close grained. The red ore is the more valuable. The carbonate or unaltered ore is dense, close grained, and bluish or grayish in color, and therefore is known as the blue limestone or the gray limestone ore. Most of the furnaces used the limonite ore, as the furnace men were unable to produce a coarse-grained foundry iron from the carbonates. The

following analyses illustrate the character of both the limonitic and the sideritic phases of the limestone ore:

Analyses of limestone ores of Kenova quadrangle.

	1.	2.	3.	4.	5.	6.	7.
Ferric oxide (Fe_2O_3)	57.551	51.802	71.680	60.206	None.	65.395	31.544
Iron carbonate ($FeCO_3$)		10.594			62.002	None.	30.708
Alumina (Al_2O_3)	6.017	4.523	4.155	1.044	2.900	3.484	1.779
Manganese oxide (MnO)	[a] .130		.090	Trace.	Not est.	Not est.	
Manganese carbonate ($MnCO_3$)		Trace.			.553		.060
Calcium carbonate ($CaCO_3$)	.150	7.480	.380	.285	6.880	8.580	2.730
Magnesium carbonate ($MgCO_3$)	.758	.440	.050	.381	2.243	[b] 1,988	.141
Phosphoric anhydride (P_2O_5)	.057	.570	.084	.161	.149	.441	.421
Sulphuric anhydride (SO_3)	.105	.089	.270	.852	.302	.386	.491
Silica (SiO_2) and insoluble silicates	25.450	15.730	12.650	25.930	22.660	10.480	25.430
Combined water (H_2O)	10.300	8.772	10.800	[c] 11.141		9.346	6.523
	100.518	100.000	100.159	100.000	97.689	100.000	100.000
Metallic iron (Fe)	40.285	41.357	50.176	42.144	29.932	45.776	36.627

[a] Brown oxide of manganese. [b] Magnesia. [c] And loss.

1. So-called slate ore, occupying the place of the limestone ore, from ridge between Cane Creek and Wilson Creek. Hunnewell furnace. Kentucky Geol. Survey, vol. A, pt. 1, p. 114. Robert Peter and J. H. Talbutt, analysts.
2. Limestone ore from Hoods Creek near Bellefont furnace. Idem, p. 20.
3. Limestone ore from the Graham bank, near Willard, Carter County. Average sample from the stock pile. Idem, p. 55.
4. Limestone ore from Brush Creek, Pennsylvania furnace. Idem, p. 114.
5. Gray limestone ore, from J. P. Jones's drift near Ashland. Selected from the interior of the bank. Idem, p. 37.
6. Same as No. 5, but from exterior portion of the bank. Analyses 5 and 6 show well the changes which occur when the original ore is exposed to the atmosphere and surface waters.
7. Gray limestone ore from Mount Savage furnace, Carter County. Idem, p. 51.

Analyses 1 to 4 and 6 represent limonites; 5 and 7 carbonates.

The analyses given above will also be found in P. N. Moore's report on the iron ores of Boyd, Greenup, and Carter counties.[a] The samples were collected by Mr. Moore.

The following table shows more concisely the amounts of metallic iron, sulphur, and phosphorus in both varieties of ore at the principal limestone ore horizons:

Average iron, sulphur, and phosphorus content in limestone ores.

Name of ore.	Constituent.	Limonites.		Siderites.	
		Per cent.	Analyses averaged.	Per cent.	Analyses averaged.
Vanport ("Hanging Rock") limestone ore	Metallic iron	43.40	4	30.61	2
	Sulphur	.132	4	.15	2
	Phosphorus	.090	4	.174	2
Maxville limestone ore	Metallic iron	47.79	7	35.05	4
	Sulphur	.089	2	.81	3
	Phosphorus	.147	7	.20	4

The amounts of ferric oxide and iron carbonate in the analyses at the top of this page show the fundamental difference between the oxidized and unoxidized ores. The amount of metallic iron in the

[a] Kentucky Geol. Survey, vol. C, 1884, pp. 90, 92.

limonites ranges in general from 40 to 50 per cent, rarely going above or below these limits. In the unaltered ores the metallic content is much lower, ranging from 25 to 40 per cent. The remaining constituents are variable, but silica and insoluble silicates are high. Sulphur is low, except in analysis No. 4; phosphorus is in general high. The last table also indicates these facts.

MAXVILLE LIMESTONE ORE.

Geologic position.—The lower of the important limestone ores rests directly upon the Maxville limestone, as shown by the section obtained at Olive Hill, Carter County (pp. 118–119).

Extent.—The limestone itself is above drainage level in the valleys of Everman Creek, North Fork of Oldtown Creek, and Tygarts Creek, in the northwest corner of the quadrangle. It is of very scant extent in this area, but to the west and nothwest its outcrop is generally above drainage level. The red line on the map (Pl. I), representing the fire clay lying above the limestone, may be taken also to represent the top of the Maxville limestone and its overlying ore, where the latter is present.

Character.—Where exposed on Everman Creek the limestone is from 20 to 25 feet thick. West of the area it is much thicker, locally reaching 100 feet and more, but in some places it is entirely wanting. Many of the deeper wells drilled for oil and gas have penetrated this limestone and proved it to be very thick and generally persistent over all this area. Sections of these deep wells are given on Pl. VI. The limestone is the usual bright-gray variety, and has been burned and used for fertilizer, for which purpose there seems to be an ample supply. It is not improbable that it may also prove suitable for the manufacture of Portland cement.

The iron ore overlying this limestone is erratic in occurrence and thickness, and in these respects is like the ore associated with the Vanport ("Hanging Rock") limestone. In quality it is comparable with that ore, and its content of metallic iron in its altered and unaltered phases is similar to that of the higher ore. It is apt to be more siliceous than the Vanport ore and in many places contains too much sulphur. On the whole it has proved to be one of the most valuable ores in this part of Kentucky.

ORIGIN OF LIMESTONE ORES.

An extended description of the origin of the limestone ores is hardly appropriate in this bulletin. For those interested in the theoretical side of the subject Moore's description[a] will be found most interesting and suggestive. As a result of studies made by the writer

[a] Kentucky Geol. Survey, vol. C, 1884, pp. 83–88, 94.

in the course of mapping this region in the summer of 1905, certain conclusions were reached which are summarized in an article in Economic Geology.[a]

BLOCK ORES.

Geologic position.—Most of the block ores are found in the Pottsville formation and in the lower part of the Allegheny formation. They have been separated by Moore into two groups with reference to their stratigraphic position—the upper block ores and the lower block ores. The former occupy the interval from 90 feet below the Vanport limestone to about 50 feet above it, and the lower block ores are confined to the lower 125 feet of the Pottsville. The skeleton section (fig. 20, p. 123) shows their relative positions.

Extent.—The area in which the block ores occur is along the western and southern edges of the quadrangle, chiefly west and south of the line of outcrop of the Vanport limestone. The lower block ores are mostly confined to the territory west of Little Sandy River, but the area occupied by them in this section of the quadrangle is a small part of their extent in this portion of the State. The upper block ores are more widely distributed in this particular area, their boundary extending to the east beyond that of the lower block ores and the Vanport limestone.

Character.—Like the limestone ores, the block ores occur both in the oxidized condition and as unaltered carbonates. They are characterized by being more persistent than the limestone ores and by more uniform thickness in individual beds, but they vary greatly in thickness and quality among themselves. Their most common impurity is sand. They are leaner ores, as a rule, than the limestone ores, and the lower block ores are inferior to the higher block ores. Their richness in iron apparently bears an inverse relation to their thickness, for it has been commonly observed that the leanest ores are the thickest, and vice versa. The following table shows their content in metallic iron, sulphur, and phosphorus:

Average iron, sulphur, and phosphorus content in block ores.

Kind of ore.	Constituent.	Limonites.		Siderites.	
		Per cent.	Analyses averaged.	Per cent.	Analyses averaged.
Upper block ores	Metallic iron	43.85	12	34.42	4
	Sulphur	.204	10	.444	4
	Phosphorus	.161	10	.229	4
Lower block ores	Metallic iron	33.48	10	29.74	4
	Sulphur	.137	9	.088	4
	Phosphorus	.238	9	.159	4

[a] Phalen, W. C., Origin and occurrence of certain iron ores of northeastern Kentucky: Economic Geology, vol. 1, No. 7, 1906, pp. 660–669.

KIDNEY ORES.

Geologic position.—Most of the kidney ores which have proved of value have been found in the lower part of the Allegheny formation. The more important range from about 40 or 60 feet to 100 feet above the Vanport limestone. In this interval there are from three to six beds of kidney ore of local importance. The lower of the more important ores has been called the yellow kidney ore. It lies about midway between the Winslow coal and the Coalton coal. Since most of the oxidized kidney ore has a yellow color, due to limonite, this name is not distinctive, but it has been commonly applied to the ore at this particular horizon. About 50 feet above the yellow kidney ore and 25 to 30 feet above the Coalton coal is another horizon of fairly persistent kidney ore called the red kidney ore, from the prevailing color of the weathered material. Other kidney ores occur in the Allegheny formation above the red kidney, but they are not so important as the two just mentioned.

Extent.—The western and southern boundaries of the kidney ores coincide roughly with the line representing the outcrop of the Vanport limestone and clay. Beyond this boundary, to the south and west, these ores are of minor importance. Within the arc formed by the outcropping Vanport limestone and clay these ores will be found in a zone of a mile or more in width. They occur in the hills along Ohio River and generally over the northern part of Boyd County, where they have been extensively benched. They are found in Carter County near Willard and also in the region between Little Sandy River and East Fork. In Lawrence County, as a rule, they have been very little explored.

Character.—The name of these ores is very suggestive of their physical appearance. Though occurring at perfectly distinct geologic levels, they do not form continuous beds or layers of ore, but are scattered through zones from 3 to 6 feet thick. Like the limestone and block ores they are found in all stages of transition from the pure carbonate ore, unaltered by atmospheric influences, to practically pure limonite on the outcrop. Their origin seems to be fairly obvious. It is quite probable that they have originated in much the same way as limestone and other concretions—that is, by the gradual accretion of ferrous carbonate from the surrounding beds. This segregation has probably been chiefly lateral, for otherwise the definiteness of geologic level, which is so common, would hardly persist, and the kidneys would be scattered throughout the shale and sandstones. The fact that the nodules coalesce into peculiar shapes strongly suggests such origin. Furthermore, the beds whence the nodules must have derived their ferruginous matter must have been rich in iron. These beds thus represent a period of deposition of

highly ferruginous sediments. Analyses of five samples of oxidized kidney ore collected in this region give the following averages: Metallic iron, 43.372; sulphur, 0.049; phosphorus, 0.166. These figures show that these ores are comparable with the limonite phases of the limestone and block ores.

BLACK-BAND ORES.

The term black-band ores is applied to beds of carbonate of iron with more or less bituminous and earthy matter associated. A notable occurrence of this ore is on the property of the Torchlight Coal Company on Levisa Fork, in Lawrence County. The deposit lies about 15 feet below coal No. 4 and is from 8 to 12 feet thick, consisting of layers of black or carbonaceous siderite, from 1 inch to 3 inches thick, alternating with thin layers of bituminous shale. The ore, which carries 55.12 per cent of iron carbonate, compares favorably with the Scotch black-band ores. An analysis of the ore from this locality follows, together with analyses of a similar ore from Perry County, Ohio, and of one from Scotland. These were kindly furnished by Col. Jay H. Northup, of Louisa.

Analyses of black-band ores.

	Threemile Creek, Kentucky.	Perry County, Ohio.	Scotch black band.
Iron carbonate ($FeCO_3$)	55.12		
Ferrous oxide (FeO)		43.37	
Ferric oxide (Fe_2O_3)	9.12	4.10	36.59
Manganese oxide (MnO)	2.90	1.50	2.70
Alumina (Al_2O_3)	3.26	6.05	.29
Lime (CaO)	6.12	3.00	3.24
Magnesia (MgO)	1.92	.25	1.92
Carbon dioxide (CO_2)		30.50	19.09
Phosphoric acid (P_2O_5)	Trace.	Trace.	
Sulphide of iron (FeS_2)	.78	1.56	1.63
Water (H_2O)		.58	.84
Organic matter	10.25	6.25	18.02
Insoluble residue	9.18	2.80	9.91
	98.65	99.96	94.23
Metallic iron	36.96	36.49	25.63

SUMMARY.

The ores of this part of Kentucky practically ceased to count as sources of iron some time ago. In spite of this fact it has been thought advisable to give a brief outline of their geology and occurrence. Though they have little value at present, they may be more important in the future. When the various ore beds were worked, the oxidized material at or near the outcrop was sought for, as the furnace managers were professedly unable to work the blue or gray carbonate and produce the desired coarse-grained foundry iron. The oxidized ore was obtained by benching or stripping, a process which,

though economical for ore occurring at the outcrop, could not be carried into the hills for any distance, and thus but an insignificant percentage of the ore bodies has been removed from the hills. The remaining ore is largely iron carbonate. It is very likely that when the cheaper ores now on the market become scarce and prices advance the higher grades of these ores will be worked. To reach satisfactory results the mining methods employed must be studied most carefully, but the fact that similar thin beds of iron ore have been successfully worked in Europe is significant.

LIMESTONES.

Brief descriptions have been given of two limestones, the Vanport (" Hanging Rock ") limestone near the base of the Allegheny formation and the Maxville limestone underlying the Pottsville. The Conemaugh contains higher beds of limestone, a few of which are persistent and are hence of value in unraveling the stratigraphy. Some of these beds are also of local economic importance.

The lowest limestone in the Conemaugh is the most persistent of all. It usually lies very near the top of the Mahoning sandstone, or, rather, the group of sandstone lying at the base of the Conemaugh formation. It is very widespread, but not everywhere a typical limestone in its development. Along Big Sandy River it may be traced rather continuously from the mouth of Dock Creek to Roundbottom. At some points along this stretch it is a calcareous sandstone 4 to 5 feet thick, containing abundant crinoid stems and other fossils. About one-eighth of a mile below Lockwood on the Kentucky side it has much the same character, but here it is weathered and dark in appearance and crumbles easily under the hammer. In the hills back of Cassville it is a fossiliferous shale and is closely underlain by a thin bed of coal, called the Mason coal by I. C. White,[a] and probably correlating closely with the Brush Creek coal of western Pennsylvania. Throughout the southern part of Boyd County it is very persistent, but much of it is too sandy to burn for fertilizer. In the hills east and west of Willard and on most of the streams flowing into Little Fork from the east it is 4 to 5 feet thick. In this region it is siliceous and does not react with acid on the weathered surface, but on being broken it is found to contain much lime. At Willard it occurs 180 feet above the Coalton coal and about 230 feet above the Vanport limestone. When burned this limestone will probably yield a fairly satisfactory fertilizer. This limestone is probably the representative of one of the Cambridge limestones of the Ohio Geological Survey. The horizon is in many places char-

[a] West Virginia Geol. Survey, vol. 2, 1903, p. 280.

acterized by two calcareous beds lying a small distance from one another, as indicated in the following section:

Section of Cambridge limestone 1 mile west of Potomac on Whites Creek.

	Ft.	In.
Concealed.		
Sandstone, fossiliferous	4	
Shale	14	
Limestone, crinoidal		6
Shale, blue	1	

A short distance away, near the residence of J. L. Bowling, the following section was measured:

Section of limestone near residence of J. L. Bowling, west of Potomac, Ky.

	Feet.
Sandstone, massive	30
Concealed	15
Sandstone, laminated	2
Concealed	23
Sandstone, fossiliferous	4
Shale	23
Limestone	1
Shale	5

The fossiliferous sandstone and the limestone lying from 14 to 23 feet below may represent the upper and lower Cambridge limestones of Ohio.

About 80 to 100 feet above the Cambridge limestone is another limestone, also largely siliceous, which probably corresponds to the Ames of the Ohio and Pennsylvania surveys. It is seen at many places on the headwaters of East Fork of Little Sandy and is rather persistent in the hills east and southeast of Cassville, W. Va. In the latter region much of it is characterized by calcareous pebbles on its outcrop. This limestone is possibly valuable for fertilizer and may repay careful prospecting. Other limestones have been observed higher in the Conemaugh at 70 and 120 feet above the Ames. These higher Conemaugh limestones are generally characterized on their outcrops by the presence of a few limestone pebbles. Like the lower limestones, they may prove locally valuable.

BUILDING STONE.

The only rock suitable for building stone in this area is sandstone, and of this there is a great abundance. As a rule this rock will not bear the cost of transportation, but as a local building stone it has proved of value in the construction of culverts for the railroads which pass through the area and also in the construction of chimneys, fireplaces, etc., all through the country. Some of this sandstone has also been used in the construction of dwellings. Very little of it, if

any, can be cut into blocks of any considerable dimensions, but for rougher purposes it serves as a cheap and very accessible source of supply.

Most of the sandstone in this area is micaceous, much is feldspathic, and as a rule it contains iron oxide. It ranges from very fine-grained to conglomeratic, in which few of the quartz pebbles exceed an inch in their largest dimension. A large amount of this sandstone is friable, disintegrating readily to fine sand. Such rock was used in the construction of a residence and of a building in Ashland, and so far as known proved satisfactory. It would appear, therefore, that freshly cut blocks, even of this friable sandstone, season fairly well and become resistant.

In the Conemaugh formation the most important sandstone lies at its base and is known as the Mahoning sandstone. This sandstone is well exposed along Big Sandy River near its mouth, in both Kentucky and West Virginia. Near Kenova it appears to be thick bedded enough to supply dimension stone. At this point, besides being very massive, it is very coarse grained and locally conglomeratic. It has been used by the Norfolk and Western Railway in this locality. To the south, up Big Sandy River, it is above drainage level nearly to the mouth of Dock Creek in West Virginia and to Savage in Kentucky. In building the Norfolk and Western Railway and in the recent changes in grading the Chesapeake and Ohio Railway much of this rock has been used. A higher sandstone in the Conemaugh formation has been quarried for local purposes on Whites Creek, near Egypt. The Conemaugh also contains other sandstone beds which, though suitable for local purposes, are not sufficiently valuable to export.

Sandstone from the Allegheny formation has been used along Ohio River opposite Ashland. At this point the sandstone above the Coalton coal thickens abnormally and has been quarried by the Norfolk and Western Railway for use along its line. It has furnished much rock of fair dimensions.

The Pottsville formation contains many sandstones of considerable thickness, much of which has been used in the construction of the Norfolk and Western Railway along Tug Fork, and by the Chesapeake and Ohio Railway on Levisa Fork. The Homewood or upper sandstone member of this formation outcrops near Ashland and occurs as a very massive cliff between the eastern limits of the city and Cliffside Park. The rock has been used with very satisfactory results in the construction of dwellings. Lower sandstones of the Pottsville have proved locally valuable.

GLASS SAND.

Some of the sandstones in this quadrangle may be of sufficient purity to furnish raw material for making glass, but most of them appear to be too ferruginous for such a purpose. Some of the sand found in the flood-plain deposits may, when washed, also prove suitable. A deposit of the latter type was reported on the property of Samuel Ferguson, at North Kenova, Ohio. The Mahoning sandstone and the Homewood and other sandstones in the Pottsville appear to be of sufficient purity in places for glass making, but no definite statement can be made as to the suitability of this material at any particular point. The Mahoning near Willard and the Homewood near Mount Savage may repay careful prospecting for glass sand. Before pronouncing on the fitness of sandstone or loose sand for glass making it should be examined microscopically and chemical tests should be made to determine the amount of iron, which, if present in too large quantities, renders the glass opaque. Large amounts of aluminum and magnesia also have a deleterious effect. Better than either of these tests is a practical test of the material. It should be remembered also that some sandstones, though naturally too rich in iron for glass making, yield after crushing and washing a suitable raw product.

SALT.

Many years ago salt was obtained from wells sunk on Big Sandy River near Zelda. The old salt works have long since disappeared. South of Zelda, near Catalpa, some of the wells drilled for oil and gas have struck salt water, which is still running.

METALLIC ELEMENTS.

Numerous reports reached the writer, while working in the Kenova quadrangle, regarding discoveries of lead and other metals. Concretions containing small amounts of lead and zinc sulphides have been seen. It may be safely stated, however, that in this area the metallic elements, such as gold, silver, copper, lead, etc., occur in such small quantities that time and money spent in exploration for them will meet with but little return.

DIAMONDS.

Diamonds have been reported as having been found in Elliott County, in the peridotite described on page 21. The name of kimerlite has been applied to this rock owing to its resemblance to the diamondiferous rock of South Africa. The writer can not substantiate these reports. The peridotite is, however, characterized by the presence of numerous garnets of small size. None of gem quality,

so far as known, have ever been obtained, but it is by no means certain that they do not exist. The extent of the outcrops of peridotite is indicated on the economic map (Pl. I).

OIL AND GAS.

SUBSURFACE STRATIGRAPHY.

INTRODUCTORY STATEMENT.

In the pages dealing with the general stratigraphy of the various districts into which the quadrangle has been divided, brief descriptions have been given of the character of the rocks appearing at the surface. A knowledge of rocks lower than these has been obtained from the deep wells drilled in search of oil and gas. Some of the facts so obtained are merely supplementary to those already known, but much of the information is entirely new. It will be understood that the way in which our knowledge of these underlying rocks is obtained presupposes many factors which are liable to lead to error in attempting close correlations. First, a division of these lower rocks into well-recognized geologic units is based almost solely on variations in physical character, a standard which often fails entirely when applied to surface rocks. Second, the determination of lithologic distinctions is often left to persons incompetent to make such distinctions. Third, if measurements are not made with the steel tape other errors are likely to creep in. On the other hand, horizons at which, from a general knowledge of the underground stratigraphy of a given district, oil and gas are considered liable to occur are usually expected by the driller, and hence the position of their tops and bases is generally detected within very close limits.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

The base of the Pennsylvanian series, resting on the top of the Maxville limestone, has been chosen as a datum plane in arranging the deep-well records (Pl. VI). The Maxville limestone is present in all the sections except one shown by a well (No. 9, Pl. VI) drilled near the mouth of Blaine Creek, and serves as a convenient guide from which to reckon. The complete absence of this limestone in the Blaine Creek record is not easily explained, since the Horseford Creek well (No. 10), a mile and a half away, shows the limestone 140 feet thick. The limestone is probably present in the Blaine Creek well, but was called sandstone.

The well showing the greatest thickness of Pennsylvanian or coal-bearing rocks is the Horseford Creek well (No. 10), in which more than 1,000 feet of these rocks is represented. The explanation is that the well was started in Conemaugh rocks well up in this series. The

prevailingly sandy character of the lower part of the Pennsylvanian rocks is apparent. The line which has been drawn at the top of the lower sandstones of this series is not the top of the Pottsville, since from surface observations it is known that the Pottsville must be thicker than the intervals included between this line and the top of the Maxville limestone, as in the Shope Creek well, Summit well, Catletts Creek well, and others. This lower group of sandstones contains salt water and gas, and this fact has helped to determine the position of the correlation line at its top. It is probable that in several of the sections this lower group of sandstones may correspond to the Sharon conglomerate, which is known to consist of two members, as on Everman Creek, Carter County. The well showing the greatest thickness of Pottsville rocks is the Griffith Creek well (No. 19), which starts in rocks of this formation and reaches the Maxville limestone at a depth of 775 feet. In the southeastern part of the area, therefore, the Pottsville rocks are very nearly 1,400 feet thick, as compared with a thickness of 350 to 400 feet in the northwestern and western parts. The first figure, 1,400, added to the average thickness of Allegheny, Conemaugh, and higher rocks, makes the Pennsylvanian series in the Kenova quadrangle, in round numbers, about 2,000 feet thick. In certain sections the highest limestone plotted has not been regarded as the Maxville. In doing this each case had to be considered on its own merits in connection with the known surface geology of the immediate locality. At some points where limestone is shown on the surface on the plotted record, it is probable that sandstone has been designated as a limestone or lime by the driller.

MISSISSIPPIAN SERIES.

The Mississippian series includes the rocks from the top of the Maxville limestone to the base of the Bedford shale; no record shows the presence of red shale above the top of the Maxville. The series comprises the Maxville limestone and the Waverly group, in which is included at the base the Sunbury shale, Berea sandstone, and Bedford shale.

The Maxville limestone shows in all the sections except that of the Blaine Creek well (No. 9). It ranges in thickness from 60 feet in the Summit well (No. 3) to 345 feet in the Alum City Oil Company's Straight Creek well (No. 6) and the A. M. Holbrook well (No. 18). The latter thickness seems excessive, for near both the Straight Creek well and the Holbrook well other records show a thickness of 109 and 152 feet for this limestone. The fact that the unusual thickness of limestone is accompanied by a marked thinning of the underlying Waverly in both records is indirect evidence that the thickness of the limestone has been overestimated. The Richardson well (No. 5) shows the next lower measurement—about 270 feet. But this, too, may be excessive, for the Catletts Creek well, not over 3 miles away, shows

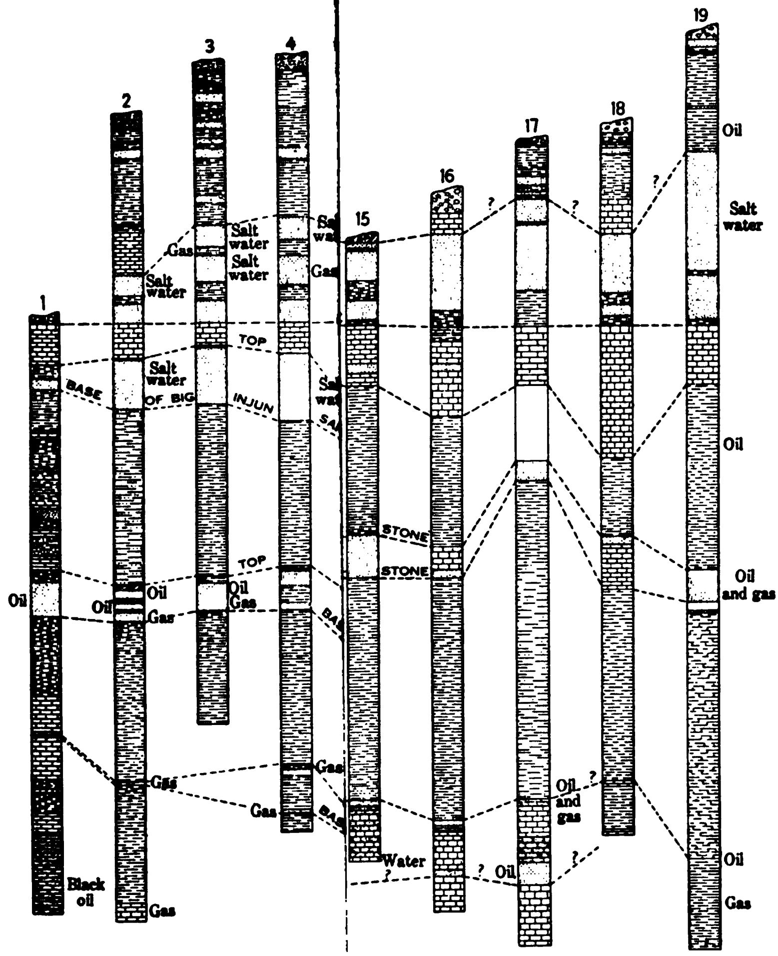
only 80 feet of limestone. The limestone shows great variation and no tendency to thicken regularly in any part of the area. Whether or not this is due to an unconformity at its top can not be stated, but it is known that an unconformity exists between the Mississippian and Pennsylvanian series in Pennsylvania and West Virginia. The Maxville limestone is the "Big lime" of the Pennsylvania drillers and corresponds to the Greenbrier of West Virginia.

The Waverly group includes the Mississippian rocks below the Maxville limestone and above the Devonian shale. At the top of this group, in the wells studied in the northern part of the quadrangle, a persistent sandstone is present. It is in places overlain by a shale bed that is usually thin, but is 40 feet thick in the Joshua Kelly well (No. 1). At Straight Creek and on Glancy Fork no sandstone appears in this position, but the Horseford Creek well (No. 10) shows 95 feet. In the Blaine Creek section 370 feet of white sandstone and conglomerate are represented in this part of the section, and without doubt part of this thickness is the upper sandstone of the Waverly. In the wells in the southern part of the quadrangle it is usually absent, except in the Jason Boggs well (No. 11), where the sandstone in this position measures 345 feet, with the underlying shales only 75 feet thick. This interpretation of the lithologic character of the rocks is open to some question, as the shale below the sandstone is everywhere much thicker than the sandstone itself. In a carefully kept record of the Guffey well, north of Grayson, no typical sandstone is reported from this position. The complete record of the well, which seems to be the only one known in this particular part of the quadrangle, is given to show the character of the underlying formations in this part of Carter County.[a]

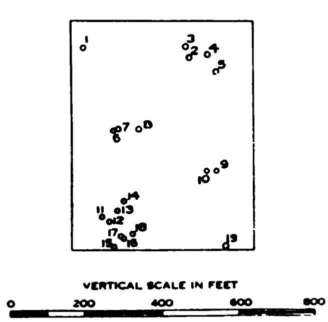
Log of Guffey well, just north of Grayson, Carter County, Ky.[b]

	Thickness.	Depth.
Carboniferous:	*Feet.*	*Feet.*
Quicksand	28	28
Slate, black	30	58
Sandstone	12	70
Slate, black	10	80
Limestone, Maxville	20	100
Shale, dark green, sandy	230	330
Slate, light gray, and sand shells	270	600
Sandstone and shale	50	650
Sandstone, slate, and shells	85	735
Slate, black (Sunbury shale)	22	757
Sand, Berea (oil and gas)	112	869
Slate, gray (Bedford)	25	894
Slate, red (Bedford)	6	900
Devonian shale:		
Slate, black	116	1,016
Slate, white	5	1,021
Slate, black	169	1,190
Slate, white	20	1,210
Slate, black	95	1,305
Slate, white	118	1,423
Limestone (oil and gas) ("Corniferous")	2	1,425
Silurian:		
Limestones, fine and coarse; strong flow of salt water at 1,475 feet	55	1,480

[a] Oil and gas: Kentucky Geol. Survey, Bull. No. 1, 1905, p. 74.
[b] The geologic units were identified by J. B. Hoeing.



1 Little Sandy Oil Co., Joshu
Euclid, Greenup Co.
2 Clinton well, George farm,
Boyd County
3 Summit well, Summit, Boy
4 Catletts Creek, 2 miles we
5 Richardson farm well, west
Sandy River, 1½ miles south
(Longabaugh well)
6 Alum City Oil Co., Straight
7 New Domain Oil and Gas
Carter County
8 New Domain Oil and Gas
farm, Glancy Fork, Carter C



[redacted]

In the record of the deep well near Central City, W. Va., the sandstone appears with a thickness of 177 feet, showing its continuation to the east of this quadrangle.[a]

Section of well on Fourpole Creek near Central City, W. Va.[a]

	Thickness.	Depth.
Carboniferous:	*Feet.*	*Feet.*
Conductor		26
Shale and lime (sand?)	94	120
Lime	7	127
Slate and fire clay	98	225
Sandstone	25	250
Shale	50	300
Sandstone	30	330
Slate, black	10	340
Sand, gray	60	400
Slate, black	10	410
Sandstone	85	495
Slate, white and blue	25	520
Sand and lime	20	540
Slate	20	560
Slate, black	175	735
Sandstone, gray	25	760
Slate, black and blue	75	835
Shale and lime	30	865
Sandstone	30	895
Slate, black	40	935
Limestone	5	940
Slate, black	30	970
Limestone (Maxville)	150	1,120
Slate	28	1,148
Sand, gray (Big Injun)	177	1,325
Shale, black	370	1,695
Limestone, hard	10	1,705
Slate, brown	25	1,730
Sandstone	25	1,755
Slate, black	10	1,765
Sand and lime	23	1,788
Slate	6	1,794
Shale, black	20	1,814
Sand, black (Berea)	97	1,911
Devonian:		
Slate	24	1,935
Slate, white	100	2,035
Lime and shale	9	2,044
Slate, black	211	2,255
Slate, brown	55	2,310
Sand and shale	45	2,355
Slate, black and blue	30	2,385
Sand, black	30	2,415
Slate, black	5	2,420
Sand, white	5	2,425
Slate, various colors	325	2,750
Sandstone	5	2,755
Limestone (part of this limestone may be upper Silurian)	215	2,970

[a] This well was drilled in 1898. The record was furnished by Thomas W. Harvey, owner.

The meager data available in this area as a whole indicate a tendency in this sandstone to die out to the south. It is the Burgoon ("Big Injun") sandstone of the Pennsylvania drillers, and probably represents the "Big Injun group" of the Kentucky Geological Survey and the Logan formation of the Ohio Survey. The thickness of the sandstone and shale ranges from 70 to 370 feet.

The underlying shales of the Waverly are from 370 to 470 feet thick across the northern part of the quadrangle, from west to east.

[a] Campbell, M. R., Description of the Huntington quadrangle: Geologic Atlas U. S., folio 69, U. S. Geol. Survey, 1900, p. 3.

In the wells in the central part of the quadrangle, except the Alum City Oil Company's well at Straight Creek (No. 6, Pl. VI), the thickness is rather uniform, ranging from 375 to 440 feet. It is fairly uniform also along the southern edge of the quadrangle, most of the wells showing about 400 feet. In most of the records the rocks are described as sand and shale, the latter usually light or gray in color, but in places dark or black. Local limestone layers are also recorded.

The Sunbury shale and Berea sandstone, near the base of the Mississippian series, consist of oil- and gas-bearing shale and sandstone from 60 to 200 feet thick. In the northern part of the quadrangle as a whole the Mississippian series averages very nearly 700 feet in thickness, but it shows a tendency to grow thinner toward the south.

DEVONIAN SYSTEM.

The records show, below the shales and sandstones at the base of the Mississippian series, a considerable body of shale, more or less calcareous, in the midst of which occurs a gas- or oil-bearing sand, probably the Ragland sand of the Kentucky drillers. In some wells this sand is underlain by a few hundred feet of black shale (Ohio shale), but in others the underlying rocks are more or less calcareous in part. It is probable that in the wells drilled in the southern part of the area (Nos. 11 to 19) Silurian limestones have been reached. They may also be reached in some of the wells near the northern edge of the quadrangle, as in that at Central City, where a part of the 215 feet of limestone at the base of the section may be Silurian. The basis for this statement lies in the fact that in the vertical section of Ohio rocks the limestones at the base of the Devonian do not exceed 75 feet in thickness at any point.[a] It is also possible that in the wells in the northern part of this area the considerable bodies of shale represented below the Ragland sand may be older than Devonian.

OIL AND GAS WELLS.

On the geologic map accompanying this report two classes of wells are represented by red and green symbols. Those in red indicate wells that are known to have produced gas in quantity; the other wells are shown in green. Nearly all the wells in this area were drilled in search of oil. In some of them oil was found, but in too small amount to pay the expense of prospecting, and some wells were practically dry. The rocks containing oil and gas are usually known to the drillers as sands. Those known to be productive in this area are described in the next section. The numbers in the accompanying list correspond to those used on the economic map (Pl. I).

[a] Rept. Geol. Survey Ohio, vol. 7, 1893, plate opp. p. 4.

Deep wells in the Kenova quadrangle.

1. Little Sandy Oil Company, Joshua Kelly farm, Euclid, Greenup County.
2. Clinton well, George farm, Shope Creek, Boyd County.
3. Summit, Boyd County.
4. Catletts Creek, 2 miles west of Catlettsburg.
5. Longabaugh well, Richardson farm, west bank of Big Sandy River, 1½ miles south of Catlettsburg.
6. Alum City Oil Company, Straight Creek, Carter County.
7. New Domain Oil and Gas Company, Straight Creek, Carter County.
8. New Domain Oil and Gas Company, L. C. Glancy farm, Glancy Fork, Carter County.
9. Mouth of Blaine Creek, Lawrence County.
10. Horseford Creek, Lawrence County.
11. New Domain Oil and Gas Company, Jason Boggs farm, Canes Creek, 6 miles northwest of Blaine, Lawrence County.
12. New Domain Oil and Gas Company, John Boggs farm, Canes Creek, 4 miles northwest of Blaine, Lawrence County.
13. New Domain Oil and Gas Company, J. F. Cooper farm, Lick Fork of Cherokee Creek, 5 miles northwest of Blaine, Lawrence County.
14. New Domain Oil and Gas Company, J. A. Young farm, Cherokee Creek, Lawrence County.
15. Laurel or Broas well, Lower Laurel Creek, Lawrence County.
16. New Domain Oil and Gas Company, H. H. Gambrill farm, Big Blaine Creek, 1 mile west of Blaine, Lawrence County.
17. Berry well, mouth of Cane Creek, Lawrence County.
18. New Domain Oil and Gas Company, A. M. Holbrook farm, one-fourth mile northeast of Blaine, Lawrence County.
19. Griffith Creek, 7 miles southeast of Louisa, Lawrence County.
20. Oil well, Catletts Creek.

21, 22. Forestdale, Ohio.

23. Frank Crank, Yatesville.
24. George Carter, near Yatesville.
25. Hannah Lackey, near Yatesville.

26, 27. Land & Carter, near Yatesville.

28. Keffer well, Upper Stinson Creek.

OIL AND GAS SANDS.

CARBONIFEROUS ROCKS.

Salt sand.—Fresh water is reported in the Summit well (No. 3), well up in the Carboniferous, 425 feet above the top of the Maxville limestone, and also in the Straight Creek well (No. 6), 441 feet above the same datum plane. The first prominent gas and salt-water horizon occurs in the interval of 250 feet above the Maxville, in the lower part of the Pottsville formation. This salt-water bed probably corresponds in places to the Sharon conglomerate. The oil and salt-water sands are either two or three in number, and may be regarded as the equivalent of the Salt sand to the north in Ohio, but in Washington and Monroe counties, Ohio, the name Maxton sand has been applied to the sand resting directly upon the Maxville lime-

stone. From this bed the old salt wells on Big Sandy River near Zelda obtained their salt water.

Big Injun sand.—The sandstone containing salt water lying directly below the Maxville limestone, or separated from it by a few feet of shale, belongs to the "Big Injun group," or Logan formation of Kentucky and Ohio. The term "group" is hardly applicable in the Kenova quadrangle, as most of the records show a single sandstone bed from 30 to 175 feet thick. In the Blaine Creek well (No. 4) 370 feet of sand and conglomerate are indicated in this part of the section, but, as has already been pointed out, some of this is probably the Maxville limestone. Nothing but salt water has been reported from this sandstone.

Berea sandstone.—In the rocks below the Big Injun sand an occasional show of oil is reported, but no persistent oil- and gas-bearing rocks are encountered until the drill reaches the Sunbury shale and Berea sandstone. Most of the records studied show between the shale of the Waverly above (Cuyahoga?) and the Devonian black shale below a group of sandstones with shale layers, which are referred to the Sunbury shale and Berea sandstone. In many of the sections the well-defined sandstone occurring below the black shale of the Waverly is without doubt the Berea sandstone proper, but in certain of the sections showing several sandstone bands the boundary has been drawn on the lowermost where there seemed no positive evidence to the contrary. Where a single layer of both shale and sandstone has been recognized in the driller's logs the thickness does not exceed 120 feet. Both oil and gas are reported from the Berea, but in no instance has the production been on a profitable scale.

DEVONIAN ROCKS.

Ragland sand.—The Devonian shale carries some oil disseminated through it, but the first persistent gas- and oil-bearing stratum in this rock is a sandstone band a few hundred feet from its top. Some of the records show this sandstone embedded in shale, as in the Clinton well (No. 2), the Catletts Creek well (No. 4), and the Richardson or Longabaugh well (No. 5); but in others it rests upon or is associated with limestone. It is barely possible that the Ragland sand of the southwestern part of the quadrangle, found resting upon limestone, may not be the same sandstone as the gas-bearing rock of the Catletts Creek and Clinton wells, but the presumption is strongly in favor of this correlation. The reason for this question lies in the fact that in the Clinton, Catletts Creek, and Longabaugh wells the gas-bearing sand is underlain by considerable bodies of shale, which are described in the Clinton record as black and white. In some wells (Nos. 6 and 19) the rock at the Ragland horizon is probably a lime-

stone. In the wells where this sandstone is underlain by shale (Nos. 2, 4, and 5) rocks earlier than Devonian may be represented. This gas-bearing sandstone, regarded as the Ragland, is in most places a very thin band, but at the John Boggs well (No. 12) and the J. A. Young well (No. 4) it is reported to be more than 100 feet thick. In Bath County in the Ragland field none of the records show a thickness of the oil-bearing stratum greater than 25 feet.[a] This sand furnishes the high-pressure gas on Catletts Creek, but there the sandstone occurs in two benches. At the Jason Boggs well on Canes Creek, Lawrence County, gas containing much hydrogen sulphide was encountered at this horizon, with a rock pressure of 350 pounds.

PRODUCTION.

Most of the wells drilled in this area report a small production of oil and gas, but so small as not to be profitable. Two gas wells are notable exceptions. The well drilled on Catletts Creek struck gas in a 9-foot layer of sandstone, thought to correspond to the Ragland sand, at a depth of 1,979 feet. The pressure recorded was 975 pounds. This gas is now piped to Catlettsburg. At the Jason Boggs well on Canes Creek, Lawrence County, gas was encountered in the interval from 1,672 to 1,697½ feet below the surface; also in the Ragland sand. The volume was reported to be 750,000 cubic feet per twenty-four hours when the gas was tapped, and the rock pressure to be 350 pounds. The gas was heavily impregnated with hydrogen sulphide.

TOPOGRAPHIC DATA.

TRIANGULATION STATIONS.

The topographic work for the map of the Kenova quadrangle is based on triangulation stations, two of which are found within the limits of the quadrangle and several outside of its borders to the north, south, and northwest. The stations north and northwest of the area, some of which are in the State of Ohio, were established by the Coast and Geodetic Survey, to which the writer is indebted for the information regarding them. The four triangulation stations represented south of the area in the accompanying figure were established by the United States Geological Survey. The two stations on this quadrangle are designated by the names Oakland and Buena Vista. Oakland, named from Oakland furnace, on Chadwick Creek, Boyd County, is situated at the highest point on the ridge at the head of Campbell Run and Laurel Creek. Buena Vista, so called from Buena Vista furnace, is situated on the ridge northwest of Straight Creek, on the dividing line between Greenup and Boyd counties. The accompanying figure (21) shows the relative positions of these triangulation stations. Descriptions of their exact locations follow.

[a] Kentucky Geol. Survey, Bull. No. 1, 1905, pp. 59, 60.

Geographic positions of stations.

[Locality, 39th parallel. United States standard datum. States of Ohio and Kentucky.]

Station.	Latitude.			Seconds in meters.	Longitude.			Seconds in meters.
	°	′	″		°	′	″	*Meters.*
Round Top (1885)	38	36	35.371	1,090.7	83	12	37.795	914.5
Oakland (1884)	38	21	46.466	1,432.7	82	38	52.881	1,283.8
Buena Vista (1884)	38	23	44.026	1,357.5	82	48	21.664	525.7
Howland (1885)	38	37	47.115	1,452.8	82	50	20.415	493.7
Fradd (1885)	38	35	46.927	1,447.0	82	33	06.031	145.9
Gould (1885)	38	38	27.582	850.5	82	49	56.728	1,372.0
Scioto (1885)	38	45	47.719	1,471.5	83	03	03.622	87.4
Ironton, cupola of Kelly's house (1885) [a]	38	31	59.67	1,839.9	82	40	10.36	250.9

Station.	To station—	Azimuth.			Back azimuth.			Distance.	Log. distance.
		°	′	″	°	′	″	*Meters.*	*Meters.*
Round Top (1885)	Scioto	219	07	22.42	39	13	21.31	21,969.63	4.3418228
	Howland	263	23	19.14	85	31	36.82	19,416.44	4.2881697
Oakland (1884)	Gebhardt	241	41	35.15	61	56	19.22	39,117.34	4.5923693
	Davis	272	40	01.16	92	50	59.31	25,780.11	4.4112848
Buena Vista (1884)	Fradd	224	47	25.11	44	56	55.06	31,451.43	4.4976404
	Oakland	284	39	44.46	104	45	37.60	14,273.64	4.1545347
Howland (1885)	Gould	264	43	17.96	84	49	09.90	13,690.61	4.1364228
	Buena Vista	328	23	44.36	148	30	34.56	30,504.44	4.4843631
Fradd (1885)	Wray	271	00	59.69	91	04	23.75	7,917.68	3.8985980
	Gebhardt	285	51	33.48	106	02	43.60	27,068.65	4.4324666
	Oakland	18	00	13.70	197	56	37.88	27,244.57	4.4352799
Gould (1885)	Fradd	281	21	56.10	101	32	26.91	24,947.67	4.3970300
	Oakland	332	25	05.92	152	31	59.19	34,808.56	4.5416860
	Buena Vista	355	09	35.66	175	10	34.86	27,341.14	4.4368167
Scioto (1885)	Fradd	292	56	07.10	113	14	50.55	47,235.01	4.6742640
	Gould	305	26	57.47	125	35	09.49	23,361.24	4.3684959
	Howland	339	58	48.81	160	01	08.36	15,770.77	4.1978529
	Round Top	39	13	21.31	219	07	22.42	21,969.63	4.3418228
Ironton, cupola of Kelly's house (1885) [a]	Fradd	235	39	56	55	44	20	12,435.5	4.094663
	Oakland	354	19	06	174	19	54	19,000.8	4.278771

[a] No check on this position.

ROUND TOP.

Round Top station is situated in Lewis County, Ky., about 5 miles west of Quincy, on a hill just back of L. Johnson's house, well known in this locality as Round Top and as being the highest point along Ohio River between Pittsburg and Cincinnati. The whole top of the hill was cleared off, with the exception of two pine trees.

The station is marked by an earthen pyramid buried 3 feet in the ground. Above this and coming to the surface is a tile pipe 6 inches in diameter and 2 feet long. This is filled with cement and a nail in the center marks the center of the station. Four tile pipes 2 feet long and 4 inches in diameter, filled with cement, with a nail in the center, were put down as reference marks—north, east, south, and west—their tops being level with the surface of the ground. The following measurements were made with steel tape: From station to nail in pipe north (true), 5.88 feet; to nail in pipe east, 6.22 feet; to nail in pipe south, 5.95 feet; to nail in pipe west, 5.93 feet.

SCIOTO.

Scioto station is on the land of George Davis, about 1½ miles west of his distillery on the west side of Scioto River, which is about 1½

miles northwest of Portsmouth. A signal 96 feet high to the floor of the scaffold was erected here and theodolite No. 118 was mounted about 100 feet from the ground. Lines were opened to Peach

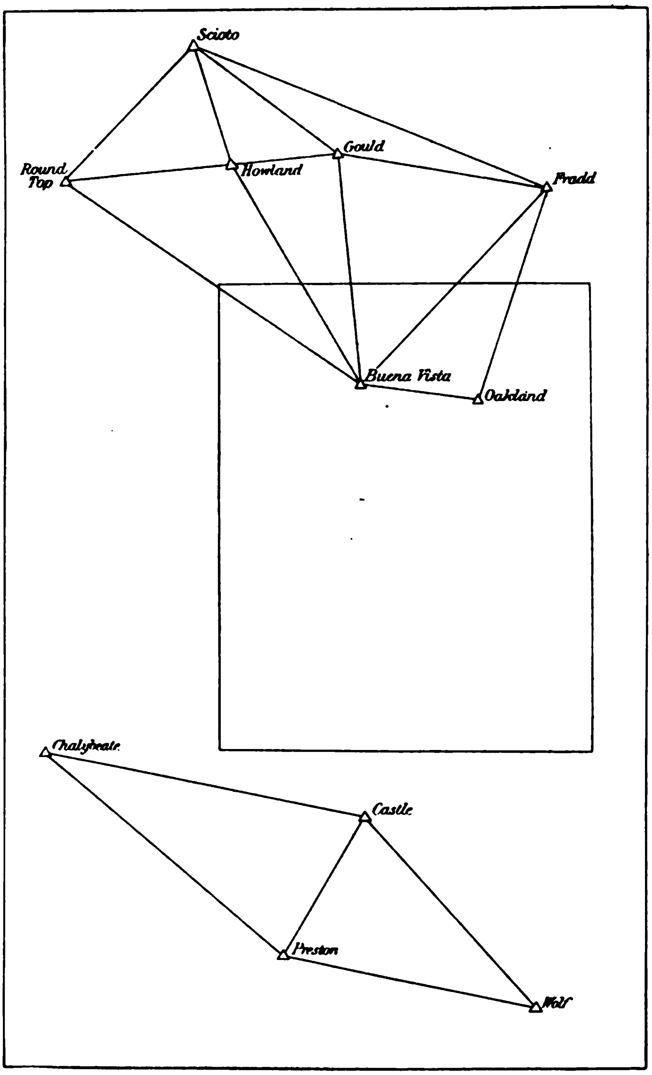


FIG. 21.—Sketch showing location of triangulation stations in and near the Kenova quadrangle.

Mount station (19 miles) by cutting on five ridges, and to Twin Creek station (13 miles) by cutting on two ridges. Fradd, Gould, Howland, Round Top, Springville, and the whole of the city of Portsmouth are open.

The station is marked as follows: A pottery pyramid was below the surface, over which was placed a 6-inch draintile 2 feet long, filled with concrete. The center is marked by an spike. Reference marks consist of 4-inch pipes, as follows: N 6.29 feet; south, 6.18 feet; east, 6.25 feet; west, 6.11 feet. T four pipes were filled with concrete, and a nail driven in each n the center.

HOWLAND.

Howland station is situated in Greenup County, Ky., between garts and Schultz creeks and between Right and Left forks of Be Creek, about 3½ miles west of Liberty, about 400 yards north of the house of James Howland, on a point of land belongin James Howe, and about 100 yards west of the main county that runs from Schultz Creek to the mouth of Brushy Creek. signal is in sight from Mr. Howland's house. A 65-foot tripod scaffold was erected here. Theodolite No. 135 was mounted on of the tripod and the observations were made from it.

The station is marked by an earthen pyramid buried 2½ feet b the surface of the ground; above this is placed a draintile pi inches in diameter and 2 feet long, the top being just even with surface of the ground. The pipe was filled with cement and a 6 spike in the center marks the station. Four tile pipes 4 inch diameter and 2 feet long, filled with cement, with a nail in the c of each, were put down as reference marks. The following mea ments were made: From station to nail in pipe north (true), feet; east, 6.05 feet; south, 5.95 feet; west, 6.10 feet.

GOULD.

Gould station is situated on the hills east of Ohio River, abo miles in an air line from the river at Franklin furnace landing. land formerly belonged to O. B. Gould, but was sold in 1884 to M Kyle & Co., of Hanging Rock, Ohio. The hill is covered with timber of second growth.

The station is marked as follows: The center by a pottery pyr sunk 3 feet below the surface; above this is a piece of sewer p inches in diameter, filled with concrete, with a nail in its ce Other pieces of sewer pipe, 4 inches in diameter, are sunk a following distances and directions: North (true), 4-inch pipe, feet; south, 4-inch pipe, 6.11 feet; east, 4-inch pipe, 5.78 feet. O west is a brass rod, one-fourth inch in diameter, driven int smoothed top of an oak stump and surrounded by a triangle of nails, distant 5.77 feet.

FRADD.

Fradd station is very near to the line between Lawrence and Aid townships, in Lawrence County, Ohio, about 100 yards south of the road running from Marion to Vesuvius furnace, about 3 miles from Marion, nearly a mile west of the white schoolhouse on the hill, on land belonging to Charles Fradd, who lives in the hollow about one-third of a mile southwest of the station.

The station was marked by an earthen pyramid, sunk 2½ feet in the ground; above this was placed a 6-inch tile pipe, 2 feet long and filled with cement; a 6-inch spike marks the station center. Four 4-inch tile pipes, 2 feet long, filled with cement, with a nail in the center, were put down as reference marks, their tops being level with the ground. The following measurements were made: From station center to nail in pipe north (true), 7.63 feet; east, 6 feet; south, 6.50 feet; west, 6 feet.

BUENA VISTA.

Buena Vista station is on the highest point of the narrow ridge about 2½ miles east of Hunnewell furnace, Greenup County, Ky. The county road from Hunnewell furnace to old Buena Vista furnace crosses the ridge, and the station is on the high point to the left of the road, called in the neighborhood the "high knob." When the ridge was cut off for charcoal a single large tree was left, in which a flag was put for use in reconnaissance. This tree was trimmed by cutting its lower branches and was left temporarily for a mark.

The station is marked at the center by a pottery pyramid sunk 3 feet below the surface. Above this was built a pier of concrete, about 4½ feet above the ground, on which was mounted the theodolite. The center of the pier above the station is marked 6 inches below the surface, at 15 inches below the top, at 6 inches below the top, and on the surface of the pier by iron spikes driven into the concrete accurately over the center of the station. A small pole was erected to observe on from Oakland, and was taken down when the pier was built. Reference marks: Two concrete piers, 6 by 6 inches and 2 feet long, with their tops even with the ground and nail in the center, one east, one west; for the north and south marks, oak stubs with nail in the top. The following are the distances: Station to nail north (true), 7.90 feet; east, 7.16 feet; south, 8.03 feet; west, 7 feet. The large chestnut oak in which the flag was placed was cut down and a pole was erected over the pier, with crotch 16 feet high and pole 12 feet above the crotch. The distance from the station to a blazed stump marked with a triangle of driven nails with a spike in the center is 17.3 feet.

OAKLAND.

Oakland station is on the highest part of the wooded hill at the headwaters of Chadwick Creek, on the land of Thomas Galligher, a few feet from the fence dividing his land from that of James L. Rucker.

The center is marked by a pottery pyramid, buried 3 feet. Over this is placed a section of 4-inch tile pipe 2 feet long, its upper surface level with the surface of the ground. This pipe is filled with and surrounded by concrete made of hydraulic cement and broken sandstone. The station center is marked on the top of the concrete by an iron spike 6 inches long, the center of the head of this spike being accurately plumbed under the center of the tripod head, on which was mounted theodolite No. 118. Reference marks consisting of 4-inch tile pipes 2 feet long, filled with concrete and sunk level with the surface of the ground, with a nail in the center of each, were placed at the following distances and directions: North (true), 5.98 feet; south, 5.02 feet; east, 6.02 feet; west, 6.06 feet.

WOLF.[a]

On sharp ridge at head of Wolf Creek, Martin County, Ky., 12 miles (air line) southwest of Warfield, on Tug Fork of Sandy River. Permanent mark: Large chestnut tree.

[Latitude, 37° 43′ 34″.4; longitude, 82° 34′ 20″.9.]

To station—	Azimuth.			Back azimuth.			Log. distance.
	°	′	″	°	′	″	*Meters.*
Castle	138	37	03.8	318	28	31.8	4.489071
Preston	101	39	08.3	281	26	22.5	4.494856
Frazier	13	12	43.8	193	09	13.7	4.569316
Willard	342	01	58.8	162	08	53.8	4.735622

PRESTON.[a]

On northeast end of Long Knob, at head of Barnett and Jennie and Little Paint creeks, Johnson County, Ky., 7 miles southwest of Paintsville.

[Latitude, 37° 46′ 57″.3; longitude, 82° 55′ 11″.6.]

To station—	Azimuth.			Back azimuth.			Log. distance.
	°	′	″	°	′	″	*Meters.*
Wolf	281	26	22.5	101	39	08.3	4.494856
Quicksand	1	28	02.2	181	27	41.1	4.520126
Frazier	332	14	31.1	152	23	43.8	4.679871

[a] This description may be found in Bull. U. S. Geol. Survey No. 122, 1894, p. 82.

SPIRIT-LEVEL WORK.

During the course of topographic work in the Kenova quadrangle numerous bench marks were established, descriptions and elevations of which are given below.

The elevations in the following list are based on a bronze tablet at Kenova, W. Va., in the west side of the door sill at the entrance to the men's waiting room at the union station. The elevation of this tablet is accepted as 566.918 feet above mean sea level. The initial height from which these elevations are derived is that determined for bench mark 316 A of the Ohio River Survey, Corps of Engineers, U. S. Army, at Catlettsburg, Ky., by the 1903 adjustment of precise leveling. The leveling was done in 1900 under the direction of W. N. Morrill, topographer; by J. E. Buford and C. H. Semper, levelmen. All standard bench marks dependent on this datum are stamped with the letter "K" in addition to the figures of elevation.

HAVERHILL, OHIO, TO GREENUP, KY.; THENCE ALONG EASTERN KENTUCKY RAILWAY TO ARGILLITE.

	Feet.
Greenup County building, clerk's office; bronze tablet set vertically in stone step at right of entrance, stamped "538 I"	540.004
Riverton, 1.5 miles south of, railroad bridge 150 feet south of road crossing, on abutment at southwest corner of bridge; chisel mark	554.70
Argillite, 1,320 feet south of, east side of north end of Argillite tunnel, 8.86 feet higher than top of rail, in sandstone ledge; bronze tablet stamped "567 K 1900"	566.442

GREENUP SOUTHWARD TO MOUTH OF WHETSTONE CREEK.

Greenup, 2.5 miles southwest of, 750 feet southwest of log house, on north side of road, north of road center, in south end of sandstone bowlder 7 by 10 by 25 feet; bronze tablet stamped "578 I"	580.081

KENOVA ALONG CHESAPEAKE AND OHIO RAILWAY (BIG SANDY DIVISION) TO ROCKVILLE (BUCHANAN), KY.

Savage, 2.6 miles north of, on west side of highway or crossing 40 feet from center of track and 10 feet from center of highway, on sandstone ledge; chisel mark	552.44
Savage, 870 feet north of station, at southeast corner of highway bridge, on bridge seat; chisel mark	541.26
Savage, in front of station; top of west rail	547.1
Savage Branch station, 1 mile south of, at David Lockwood's house, in foundation on left side of front steps; bronze tablet stamped "586 K"	586.113
Lockwood, in front of station; top of east rail	544.3
Kavanaugh Church, in front of flag station; top of east rail	581.3

BOLTS FORK NORTHWARD VIA CANNONSBURG TO ASHLAND.

	Feet.
Bolts Fork, 600 feet north of post-office, highway bridge over Bolts Fork, at southeast corner bridge seat; bronze tablet stamped "652 K"	652.567
Mavity, 0.8 mile north of, at forks of road 105 feet south of log house, 51 feet south of sycamore, on abutment at southeast corner of bridge; chisel mark	605.08
Cannonsburg, post-office building, southeast corner of, 93 feet from railroad crossing; bronze tablet stamped "604 K"	604.871
Mead station, 0.5 mile south of, on Ashland Coal and Iron Railway, 200 feet southwest of house on west side of road, corner stone west end of culvert; chisel mark	590.92
Mead station, 1 mile north of, 81 feet north of small bridge, 15 feet east of center of road, in sandstone bowlder; bronze tablet stamped "638 K"	639.221
Ashland, Chesapeake and Ohio station, on Carter avenue, between Twelfth and Thirteenth streets, south side of building, 2 feet above ground; bronze tablet stamped "556 K"	556.531

ASHLAND ALONG CHESAPEAKE AND OHIO RAILWAY VIA CATLETTSBURG TO HAMPTON.

Ashland, 1.5 miles east of, on Chesapeake and Ohio Railway, girder bridge over electric railway, on top stone at south end of west wing wall; chisel mark	555.74
Catlettsburg, Louisa street, between Franklin and Clay streets, in court-house yard, at northwest corner of clerk's office, 1 foot above water table; aluminum tablet stamped "549 K 1900"	550.303
Catlettsburg, Big Sandy National Bank (U. S. Engineer's bench mark "316 A"), on window sill; chisel mark B U □ S M	548.690

BUCHANAN WESTWARD TO MAYHEW.

Buchanan, in front of station; top of east rail	558.3
Buchanan, 150 feet south of, overhead railway bridge (B. S. 189), in top stone at east end of north pier; bronze tablet stamped "554 K 1900"	554.231
Mayhew, 850 feet west of post-office, at northeast corner of bridge over Bolts Fork, 4 feet lower than bridge, on bridge seat; chisel mark	682.18

BUCHANAN SOUTHWARD ALONG CHESAPEAKE AND OHIO RAILWAY (BIG SANDY DIVISION) TO GALLUP.

Buchanan, 1.7 miles south of, trestle No. 206, in guard rail at southeast end; top of bolt	563.03
Fuller, 300 feet north of station, 5 feet west of railroad at east edge of highway, 30 feet north of white house, in sandstone ledge; bronze tablet stamped "572 K 1900"	570.874
Poters, in front of station; top of rail	573
Louisa, U. S. Engineers' bench mark No. 13 Big Sandy, at Lock No. 3, in engineers' office yard	569.081
Louisa County court-house, north face, west side, in foundation; aluminum tablet stamped "584 K 1900"	582.419

	Feet.
Gallup, at G. C. McClure's house, in stone step to house; bronze tablet stamped "591 K 1900"	589.370
Gallup, 0.6 mile west of, U. S. Engineers' bench mark No. 5 Big Sandy, 50 feet south of west end of trestle No. 403	590.289

GALLUP WESTWARD TO PROSPERITY.

Adams, 2 miles south of post-office, at M. R. Hayes's residence, in southwest corner of foundation; bronze tablet stamped "667 K 1900"	666.591

IRAD NORTHWARD 5 MILES, THENCE SOUTHEASTWARD VIA YATESVILLE TO LOUISA.

Yatesville, 3 miles northwest of, in field on south side of and 45 feet from center of road, 135 feet from southwest corner of Green Valley schoolhouse, in north side of large sand rock; bronze tablet stamped "598 K 1900"	596.856

MAYHEW WESTWARD TO DENTON, THENCE NORTHEASTWARD ALONG ASHLAND COAL AND IRON RAILWAY TO PRINCESS, THENCE EASTWARD TO CANNONSBURG.

Denton, 4.5 miles east of, on top of hill 60 feet north of road, at old road going north, old abandoned frame house, on foundation at southeast corner; chisel square	905.39
Denton, Chesapeake and Ohio Railway station, 200 feet northeast of, 16 feet east of center of main track, in top stone; chisel mark	669.84
Denton, 1.5 miles east of, 200 feet north of road crossing at southwest end of Means tunnel on Ashland Coal and Iron Railway, 15 feet west of highway, in sandstone ledge; bronze tablet stamped "787 K 1900"	787.794
Grant station, at southwest corner of girder bridge No. 11, 30 feet west of switch stand near station, on bridge seat; chisel mark	685.92
Geigersville, 800 feet north of Rush post-office, 600 feet south of coal dump, 330 feet south of road crossing, at southwest corner of railroad bridge No. 10, in bridge seat; bronze tablet stamped "639 K 1900"	639.442
Coalton station, west of tool house near, at northeast corner of railroad bridge No. 6, in bridge seat; chisel mark	615.03

ARGILLITE SOUTHEASTWARD VIA NAPLES TO PRINCESS.

Naples, 1,300 feet north of post-office, at southwest corner of overhead highway bridge across East Fork on or near Boyd-Greenup county line, in bridge seat; bronze tablet stamped "571 K 1900"	570.839
Princess, 3.25 miles northwest of, at northeast corner of highway bridge over Williams Creek, east of log house, on abutment; chisel mark	571.67

ARGILLITE SOUTHWESTWARD VIA OLDTOWN AND EUCLID, THENCE NORTHWARD TO HEAD OF CLAYLICK CREEK (SINGLE-SPUR LINE.)

Oldtown, Mrs. Womack's house, 350 feet north of Oldtown Creek bridge, on west side of road, in foundation stone on east side of house, 6 feet from southeast corner; bronze tablet stamped "558 K 1900"	556.843
Claylick Creek, head of, on ridge where road turns to right to go down creek, near site of former schoolhouse, on north side of road between J. H. Hally's and W. J. Hally's, in ledge; bronze tablet stamped "957 K 1900"	956.345

OLDTOWN SOUTHWARD TO HOPEWELL, THENCE SOUTHWARD ALONG EASTERN KENTUCKY RAILWAY TO GRAYSON.

	Feet.
Grayson, 0.4 mile west of railroad, at southeast corner of foundation of court-house; aluminum tablet stamped "686 K 1900"	684.996

GRAYSON EASTWARD VIA SENEY TO KILGORE.

Grayson, 5.6 miles east of, on north side of road, 15 feet from center, near top of Crib Hill, in sandstone ledge; bronze tablet stamped "834 K 1900"	832.874
Kilgore, 1.3 miles west of, in road between W. C. Hargio's residence and the old store of Norton Iron Works, on sandstone bowlder; chisel mark	661.34

GRAYSON SOUTHWARD ALONG EASTERN KENTUCKY RAILWAY TO WILLARD.

Grayson, 0.5 mile south of, at southeast corner of railroad bridge over Little Sandy River, on abutment; chisel mark	588.69
E. K. Junction, 0.5 mile east of, at southwest corner of Chesapeake and Ohio Railway bridge No. 8442, on bridge seat; chisel mark	604.03
Willard, 3 miles north of, 6 feet from southwest corner of railroad bridge No. 9, on abutment; chisel mark	613.60
Willard, 1,400 feet east of station, at northeast corner of railroad bridge No. 15 over Dry Fork, in bridge seat; bronze tablet stamped "625 K 1900"	624.462

WILLARD SOUTHEASTWARD ALONG EASTERN KENTUCKY RAILWAY TO WEBBVILLE, THENCE SOUTHWARD ALONG PUBLIC ROAD VIA IRONTON HILL TO BLAINE.

Webbville, 5.8 miles south of, south of small house near south forks of road, on west side, 30 feet from center, in sandstone ledge; bronze tablet stamped "916 K 1900"	914.926
Cherokee, 0.5 mile north of mouth of Cherokee Creek, east of road, south of small house, in sandstone ledge; bronze tablet stamped "646 K 1900"	645.587

BLAINE WESTWARD ALONG BLAINE CREEK TO MARTHA, THENCE NORTHWARD VIA SARAH TO WILLARD.

Blaine, 0.3 mile west of, at northwest corner of highway bridge over Blaine Creek, on bridge seat; chisel mark	655.94
Martha, 0.4 mile north of, on east side of road, 25 feet higher than road, 36 feet north of oak tree on same side of road, in sandstone ledge; bronze tablet stamped "736 K 1900"	735.554
Fielden, 2 miles east of, at Pennington's store, mouth of Hurricane Creek, W. L. Pennington's house on south side of road, in foundation under northeast corner; bronze tablet stamped "698 K 1900"	696.921
Willard, 5 miles southwest of, on west bank of Little Fork, 0.5 mile north of Levi Pennington's, in sandstone ledge between public road and creek; bronze tablet stamped "650 K 1900"	649,725

BLAINE CREEK NORTHEASTWARD VIA PROSPERITY TO IRAD.

Irad, 2 miles west of, 0.25 mile east of log schoolhouse, on north bank of Blaine Creek, south side and 5 feet from center of road, west of house near, in large sand rock; bronze tablet stamped "630 K 1900"	629.784

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